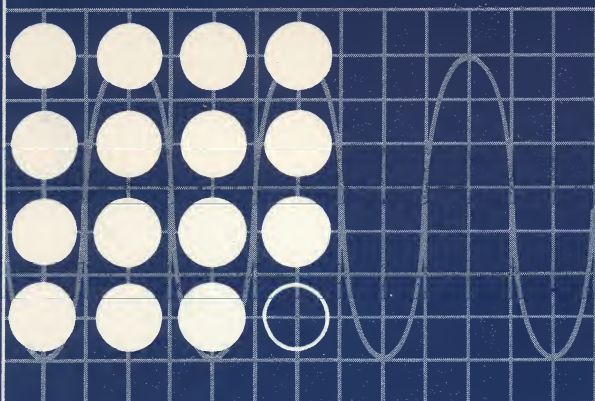




● **control
techniques
with
resonant
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relays**

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BRAMCO CONTROLS DIVISION, LEDEX INC., PIQUA, OHIO

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remote control switching with audio signals

An audio tone can be generated by an electronic oscillator or resonant reed encoder circuit, then transmitted by wire or radio. The tone activates a resonant reed relay to perform a control function.

Bramco resonant reeds permit over 50 selective control frequencies within the 67 to 1600 cps spectrum. This is assured by (1) the narrow response bandwidth of about 1% for decoders and (2) the high accuracy of Bramco reed encoders (1/10 of 1% of design frequency).

If you work with controls that select, command, regulate, or indicate, you should know about how it can be done with audio signals. Compared to other types of tone filters, resonant reeds are small and inexpensive. They give more control functions per spectrum, per size, per dollar.

This book discusses fundamental theories, definitions, and some of the more common basic applications. For recommendations for specific remote control problems, we invite you to write or call.

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SECTION I. INTRODUCTION TO RESONANT REEDS

how reed decoders work

A resonant reed relay, commonly called a decoder, is an electro-mechanical device that acts as an audio frequency filter, detector, and amplifier switch. It has one or more steel reeds suspended in a magnetic circuit that consists of a permanent magnet and a field coil. Each reed has relay contacts which close intermittently when the reed vibrates at its resonant frequency (Figures 1 & 2).

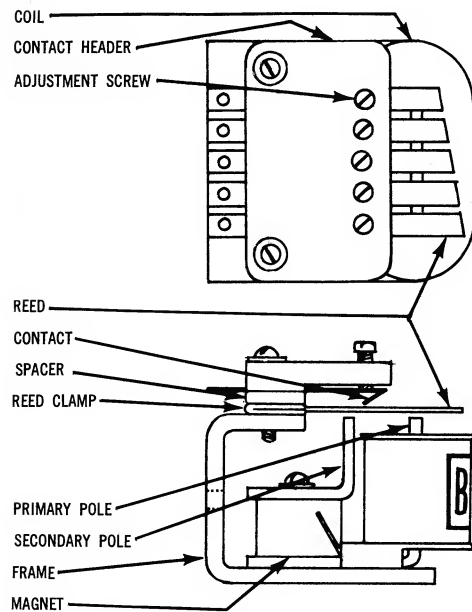


FIGURE 1. MULTI-CHANNEL
RESONANT REED RELAY

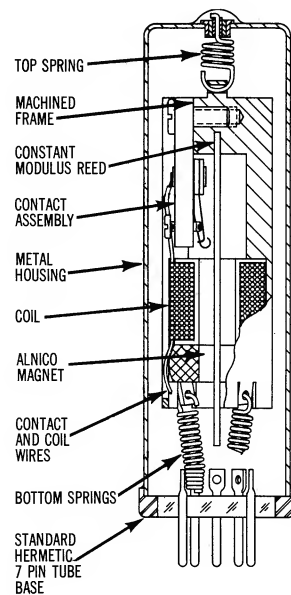


FIGURE 2. SINGLE CHANNEL
RESONANT REED RELAY

The permanent magnet provides bias to establish an operating point on the magnetization curve, high enough above zero flux density to minimize hysteresis losses. The field coil receives an AC signal and produces an alternating flux that increases and decreases the magnetic circuit flux density once each cycle. When the excitation frequency is the same as the frequency of the reed, the alternating flux causes the reed to vibrate (Figure 3).

The biasing magnet is important because it makes the reed more efficient. It reduces hysteresis losses and makes the reed vibrate once per cycle of audio input. Without the magnet the reed would have to be tuned to vibrate twice per cycle of audio input (Figure 4).

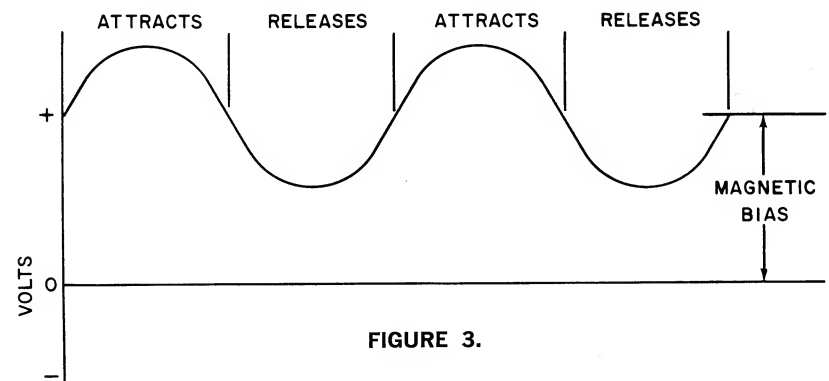


FIGURE 3.

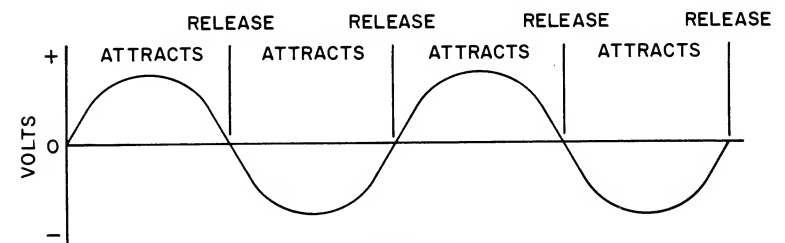


FIGURE 4.

As the reed vibrates, an intermittent contact closure is provided for about 10 to 20 percent of each cycle (Figure 5). The intermittent contact closure will supply low levels of pulsating DC which can be integrated with a capacitor to switch light loads or sensitive relays (Figure 6). Heavier loads are handled by transistor or tube amplifier circuits.

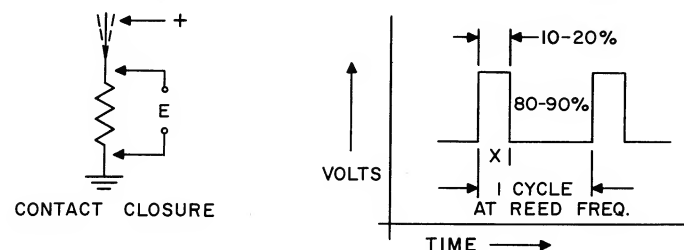


FIGURE 5.

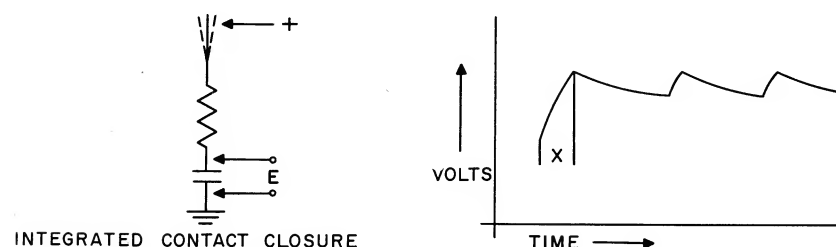


FIGURE 6.

how reed encoders work

When designed as an encoder, the resonant reed, magnet and coil assembly acts as the frequency determining element of an audio frequency oscillator. An encoder circuit consists of three basic elements: an amplifier, a feedback circuit, and a frequency control circuit. As an oscillator stabilizer the reed permits the frequency of a transistor or tube oscillator circuit to be controlled to within $\pm 1\%$ (Figure 7).

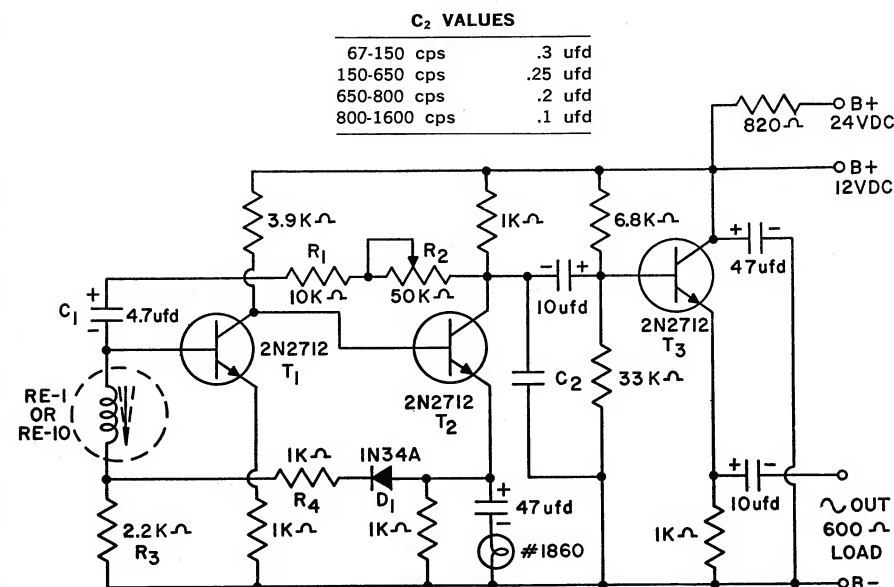


FIGURE 7. RESONANT REED STABILIZED OSCILLATOR CIRCUIT

Normal circuit noise causes an encoder reed to respond at its natural audio frequency. As the reed swings from its neutral position it approaches the magnet and causes a change in the coil flux density. The voltage generated is amplified and a feedback signal sustains the oscillation. A sharp swing in the impedance of the encoder at resonance stabilizes the oscillator frequency.

Buildup time will vary from .1 to 60 seconds, depending upon frequency and feedback setting. This delay time should be considered when designing your system. The circuit will not free-run when the reed unit is disconnected.

It is recommended that the oscillator run continuously and be keyed to the amplifier to give immediate response when a signal is desired. Sustained oscillation does not adversely affect the reed because, like a crystal, it vibrates at its natural frequency and at a very low amplitude.

resonant reeds compared to lc circuits

The application and operation of the resonant reed relay is functionally equivalent to an electrical bandpass filter. Some of the main differences are discussed below.

Narrow Bandwidth

The most significant advantage that a resonant reed relay has is its extremely narrow and precisely controlled bandwidth. Resonant reed relays, in general, have bandwidths in the order of 1 percent. This corresponds to an LC filter with a Q of several hundred. The narrow response bandwidth of resonant reeds makes it practical to design systems with 50 selective control frequencies within a spectrum of 67 to 1600 cps. Because it is expensive to build high Q LC filters, resonant reeds invariably offer the most economical solution for multi-channel systems.

Multi-Channel Economy

Resonant reeds offer the greatest economy in systems requiring multi-channel controls, particularly when the available frequency spectrum is limited, such as the 300-3,000 cps spectrum normally available over telephone lines and conventional radio communication equipment. When several decoding functions are to be performed at the same receiving station, resonant reeds offer even greater economy because multiple decoding reeds can be mounted on a single frame using only one coil and magnet. The response characteristics of multi-channel resonant reeds are essentially the same as when single channel assemblies are used.

Output Power Gain

In an LC circuit the output is proportional to the input signal. If the input voltage fluctuates the output also fluctuates. The insertion loss reduces the output significantly below the input power level. A resonant reed relay, on the other hand, has hard contacts which are completely isolated from the input. Output during the contact-make period is constant, and a low level of audio power input can switch a considerably higher output power level. A typical resonant reed relay operating at 20 milliwatts input is capable of switching 1 watt—a power gain of 50 to 1. For many applications, this “step-up” or amplifying ability of the resonant reed relay offers a decided advantage over LC control circuits.

Temperature Stability

Another major advantage of resonant reeds is excellent temperature stability. Standard models provide stability better than $\pm 0.13\%$ over

a temperature range of -40°C to $+85^{\circ}\text{C}$. A typical temperature stability for an LC circuit is $\pm 1\%$ over a temperature range of only -20°C to $+45^{\circ}\text{C}$.

Small Size

Resonant reeds require less space per channel than comparable LC circuits. A Bramco miniature model (RD-7), for example, has four channels in a package volume of about one-half cubic inch, or approximately one-eighth of a cubic inch per channel.

Of course, LC circuits may be more practical for some applications that do not require the benefits of resonant reeds. A system with a wide frequency spectrum and three LC filter circuits in three different locations, for example, obviously would not benefit from the narrow response bandwidth or multi-channel economy characteristics of resonant reeds. LC circuits in applications with broader frequency spectrums may likewise be more economical because the encoding portion of the system need not be as accurate as would be required for resonant reed decoders.

definitions of response characteristics

Resonant Frequency is the frequency of audio input at which contact closure is obtained with the least amount of power input. This point, often called threshold, is measured to establish the exact frequency of the reed. Because the reed is not intended to operate at this level, it is often not necessary to specify resonant frequency.

Natural Frequency is the frequency at which an encoder reed operates in an oscillator circuit. It is more closely analogous to a free vibration frequency than to resonant frequency, which is a forced vibration response.

Design Frequency is the reference frequency around which the tuning tolerance and bandwidth are specified. It is purely a specified frequency and can not be measured on a reed.

Frequency Tuning Tolerance is the allowable range within which resonant (or natural) frequency must be tuned (calibrated) at 25°C . It is ordinarily specified in percentage. Because the decoder reed does not operate at this point it is often not necessary to specify a tuning tolerance. Frequency tuning tolerance is always specified for an encoder reed.

Frequency Stability is the deviation of resonant or natural frequency as temperature changes. Frequency varies inversely to temperature. Bramco standard units have a stability of .002% per degree centigrade, which insures that the frequency will be held from plus .13% to minus .12% over the temperature range of -40°C to $+85^{\circ}\text{C}$ (25°C reference).

Bandwidth is the frequency range through which contact closure occurs at normal operating power level. The response curve in Figure 8 shows how different bandwidths can be obtained by using different methods of measurement. Curve A, the low frequency side of the response curve, is measured by slowly increasing or decreasing the frequency to determine the extent of contact closure. The high frequency side of the response curve can be established at either Curve B, C, or D. Curve B is measured by slowly decreasing the frequency. Curve C is measured by pulsing frequencies. Curve D is measured by slowly increasing the frequency. The faster the rise time of the pulsed signal the closer Curve C moves toward Curve D. The slower the rise time the closer Curve C moves toward Curve B (Figure 8).

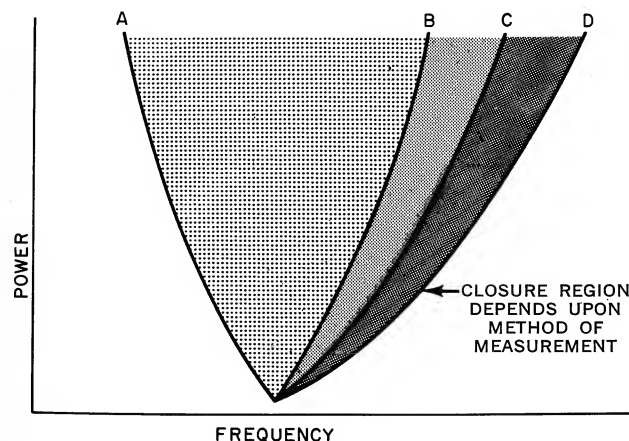


FIGURE 8.

Because Curve B is much more practical to measure with repetitive accuracy, it is always the one defined by the specifications, unless special requirements make it necessary to define Curves C or D.

Minimum Bandwidth is the range of frequencies through which contact must occur at a specified input power level (Figure 8a).

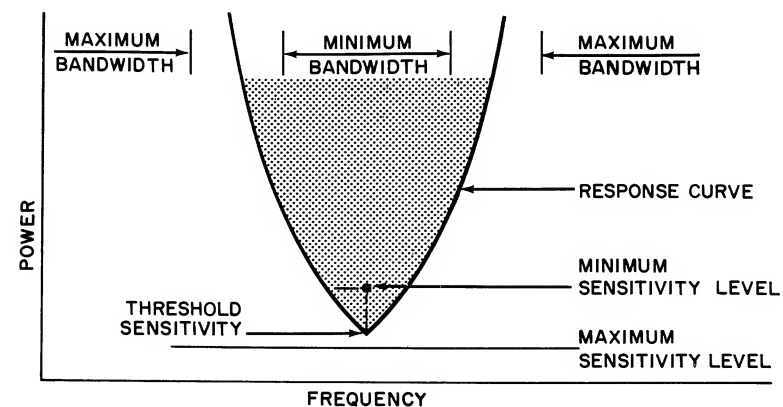


FIGURE 8a.

Maximum Bandwidth is the frequency range outside of which contact closure must not occur (Figure 8a). The maximum bandwidth specification assures against false triggering by adjacent frequencies in the system.

Sensitivity (Threshold) is the lowest power level at which contact closure occurs. This is an expression of power at which resonant frequency occurs. Sensitivity is controlled by adjusting the stationary contact air gap (Figure 8a).

Minimum Sensitivity is the power level at which contact closure must occur at design frequency. This point is used only to help establish a more specific shape to the response curve. Because a decoder is not intended to operate at this level, it is usually unnecessary to specify minimum sensitivity (Figure 8a).

Maximum Sensitivity is the power level below which contact closure must not occur. This level is established to assure a minimum contact gap for protection from noise and vibration falsing. It is always advisable to specify this level to assure system reliability against falsing (Figure 8a).

Contact Duty Cycle, sometimes called dwell time, is the percentage of time the contacts are closed per cycle. This measurement is made at resonant frequency and normal operating power level. Most Bramco models are rated at a minimum of 10%.

Duty cycle percentage is determined by manufacturing variables of the contact assembly, such as contact configuration, flexibility, and position of the contact in relation to the reed length. If all other factors remain equal, duty cycle percentage, due to the difference in reed amplitude, is greater at low frequencies and smaller at high frequencies.

Contact Rating is specified as the maximum peak current at a given DC voltage into a resistive load. Because the contacts are closed for only 10 to 20 percent of the time, it is important to allow for the **peak** current at the contacts. If the circuit being switched requires an average current of 10 milliamps, then the reed contacts, because they are closed for only 20 percent of the time, will have to switch a peak current of 50 milliamps.

Most applications switch either a capacitive or an inductive load. It is important not to exceed the peak current rating at the instant of contact closure. At this instant, it is assumed that the capacitor or inductor is at zero resistance, and the only resistance is a limiting resistor (R_1) in series with the reed contacts. The peak current at the instant of closure is therefore calculated by the formula $I = \frac{E}{R_1}$.

To insure maximum contact life, the contact circuit should be wired with positive polarity on the stationary contact. This provides a transfer of metal from the solid precious metal contact to the reed, assuring a precious metal to precious metal closure. An exception to this rule can be made only when very low current is being switched and life is not a prime consideration.

Response Time is the elapsed time between the application of the signal to the relay coil and the initial contact closure. It is measured at resonant frequency and normal operating power input. Response time decreases as the ratio between threshold sensitivity and operating level is increased. All other factors remaining constant, response time decreases when frequency is increased. Typical response times range from 200 milliseconds at 67 cps to 25 milliseconds at 1600 cps.

The Q factor for resonant reeds is not directly analogous to tuned filter circuits. Conventionally, Q is a ratio of the center frequency to the bandwidth at the 3db points. Since a resonant reed provides a fixed, hard contact as output, the most practical expression of Q is a ratio of resonant frequency to bandwidth. To make the reed Q ratio approximately equivalent to the Q of a tuned filter, the bandwidth value is measured at a level 3db (1.3 x voltage) above threshold sensitivity.

Coil Impedance is approximately 2 times the DC resistance at 400 cps. Because there is a sharp impedance swing at resonance, it is not practical to specify impedance at resonance. Other factors remaining constant, impedance will be higher with an increased reed frequency. For multiple frequency systems a nominal impedance should be selected for the total frequency range because power requirements of the reed make even large mismatches relatively insignificant.

The magnitude of impedance swing at resonance is illustrated in Figure 9. At resonance, a typical relay will exhibit an impedance approximately 3 to 4 times the DC resistance. The impedance to resistance ratio is greater for higher frequencies. The sharpness of the swing is a measure of the electrical Q of the reed, typically 200 to 300.

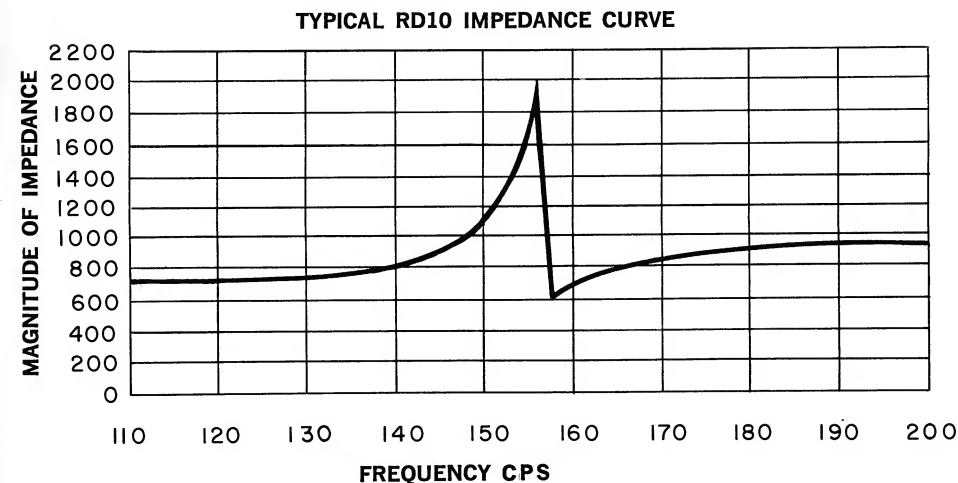


FIGURE 9.

interrelated performance characteristics

Physical characteristics, such as magnetic flux of the bias magnet, air gap, mounting, or the material and shape of the reed can be measured, controlled, and varied to obtain desired performance characteristics. Altering one physical characteristic, however, usually means a change in more than one performance characteristic.

The minimum bandwidth of a given reed relay design, for example, can be increased by decreasing the frequency tolerance or by increasing the sensitivity. Other alternatives are to reduce the Q of the reed by changing the reed material, changing the reed shape, or increasing the magnetic bias. Because a change in one performance specification usually requires a compromise on one or several other specifications, it is important to have a basic understanding of the interrelationships involved. Some examples follow:

Frequency/	As frequency is increased: - Bandwidth (%) decreases - Sensitivity decreases - Response time decreases - Contact gap decreases - Mounting method becomes more critical As frequency tolerance is increased: - Minimum bandwidth must decrease - Maximum bandwidth must increase - Minimum Sensitivity must decrease And/or: Maximum Sensitivity must increase
Bandwidth/	As the minimum bandwidth is increased: - Frequency tolerance must decrease - And/or: Sensitivity must increase - And/or: Operating level must increase - And/or: Q must decrease - And/or: Maximum bandwidth must increase As the maximum bandwidth is decreased: - Frequency tolerance must decrease - And/or: Sensitivity must decrease - And/or: Operating level must decrease - And/or: Q must increase - And/or: Minimum bandwidth must decrease

Sensitivity/	As the minimum sensitivity is increased (lower power): - Frequency tolerance must decrease - And/or: Maximum bandwidth must increase - And/or: Operating level must decrease - And/or: Maximum sensitivity must increase As the maximum sensitivity is decreased (higher power): - Frequency tolerance must decrease - And/or: Minimum bandwidth must decrease - And/or: Operating level must increase - And/or: Minimum sensitivity must decrease
Response time/	Response time can be decreased by: - Increasing frequency - Increasing operating level - Increasing sensitivity
Duty Cycle/	Duty cycle can be increased by: - Increasing sensitivity - Increasing operating level - Operating closer to resonant frequency
Impedance/	Impedance increases as frequency increases Impedance is approximately 2 times DC resistance at 400 cps.

test procedure and equipment

Figure 10 illustrates the equipment and hookup to test response of a resonant reed relay. An instantaneous and more accurate reading is obtained if the counter is set at 10-period-average rather than on direct frequency count. The ten period setting reads out with the reciprocal of the measured frequency. This provides enough additional digits for a frequency accuracy of .01 to .001 cps.

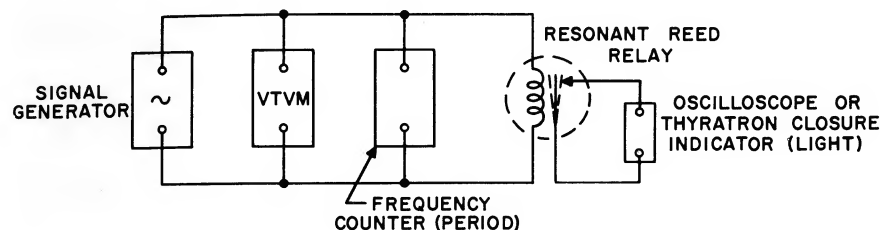


FIGURE 10. RESONANT REED RESPONSE TEST CIRCUIT

The scope is adjusted to read out the contact closure and duty cycle. If only contact closure is to be tested, a thyatron switch and light indicator can be substituted (Figure 11).

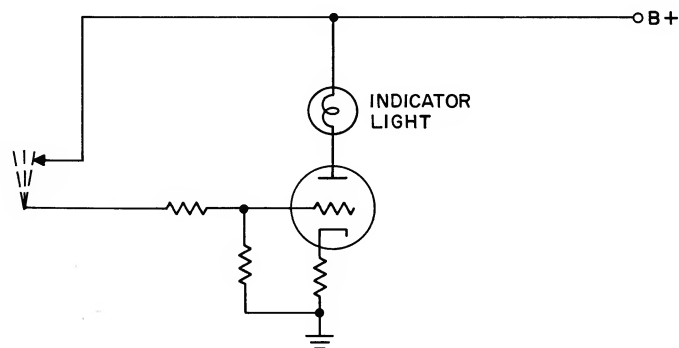


FIGURE 11. THYRATRON CIRCUIT FOR CONTACT INDICATOR

Because the method of mounting has a definite effect on frequency and sensitivity, it is important that a reed be mounted (or plugged) exactly as in the end application.

To test for **threshold** (sensitivity and resonant frequency), slowly vary the audio oscillator input level and frequency, high and low, until a power level is established at which contact closure can be made at only one frequency.

Bandwidth

To test for **bandwidth** adjust the oscillator output to the specified operating level. The lower limit is found by slowly increasing frequency until closure occurs. The upper limit is found by slowly decreasing frequency until closure occurs.

Duty Cycle

To measure **duty cycle**, adjust the oscillator to the resonant (threshold) frequency of the reed and to the specified normal operating level. The scope trace displays the percentage of closure as well as any undesirable bounce or hash. Acceptable limits are illustrated in figure 12.

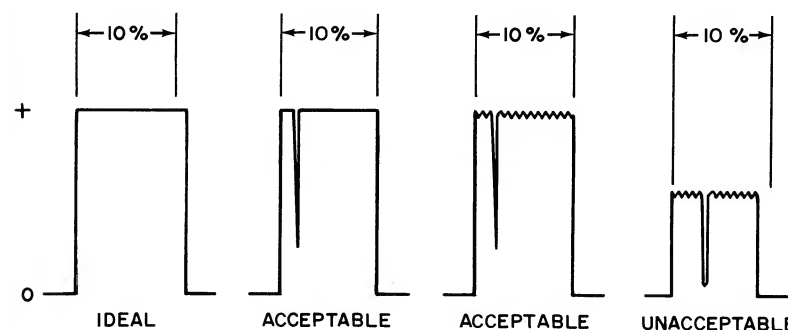


FIGURE 12. DUTY CYCLE LIMITS

Minimum Sensitivity

To test for **minimum sensitivity**, set the audio oscillator frequency at design frequency, then slowly increase the power level. Contact closure must occur at the specified minimum sensitivity level.

Maximum Sensitivity

To test for **maximum sensitivity**, set the audio oscillator power at the specified level and slowly vary the frequency above and below the design frequency. Sustained contact closure must not occur.

Response Time

Figure 13 shows a circuit for measuring response time. Adjust the audio oscillator to the resonant frequency and normal operating power level and switch the signal on. The elapsed time is shown on the counter in milliseconds.

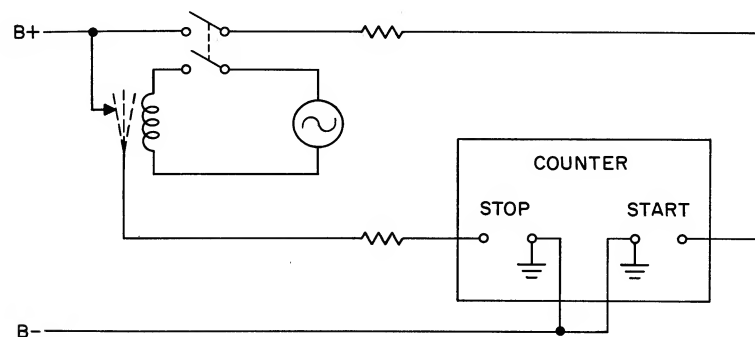


FIGURE 13. CIRCUIT FOR MEASURING RESPONSE TIME

application tips

The manufacture of a resonant reed involves precise and controlled assembly, tuning, and testing processes to assure precision and stability in the application. A slight oversight in the application, however, can easily nullify the benefits of all the care taken to manufacture the resonant reed relay. This section lists some basic tips in applying resonant reeds efficiently for optimum performance.

Mounting

Correct mounting assures that a reed will function at the factory-calibrated frequency and sensitivity. Inadequate mounting may allow energy transfer to the chassis (or printed circuit board), which will affect frequency sensitivity and other related performance characteristics.

Sealed units that include internal shock mounts should be securely and rigidly bolted or clamped to the chassis or socket. Sealed units without internal shock mounts (RD-7) should be securely screwed to a heavy bracket or rigid printed circuit assembly. When soldering to the terminals, care should be taken to avoid tension on the leads.

Fibre shoulder washers or rubber grommets should be used when mounting open frame units. This allows flexibility and provides isolation between the reed assembly and chassis. To prevent energy transfer from the frame to the chassis, standard Bramco models have mounting holes located at a null point in the frame. Angle brackets, with the assembly mounted at the null point, can be provided for applications requiring special reed orientation. Many standard Bramco models are specifically designed with built-in suspension systems for isolation against shock or vibration.

Reed Orientation:

A reed should be mounted so that its direction of travel is perpendicular to the direction of anticipated shock or vibration. Shock or vibration in the same direction of the reed travel can excite or damp reed vibration.

Recommended Frequency Range:

To obtain optimum performance of all operating characteristics, stay within the factory "recommended" frequency range of each model. The design centers for each of the operating characteristics are different for each model because of the difference in physical construction. If you exceed the "recommended" frequency range you begin to approach the limits of the operating characteristics.

Frequency Separation:

In multi-channel systems the frequencies can be very closely spaced because of the narrow bandwidth response of the decoder. With a maximum bandwidth of approximately ± 2.5 percent at the normal operating levels for most models, frequency separation of 5 percent is usually more than adequate for protection against adjacent frequency response.

Specific Frequencies

For multi-channel systems, it is best to use the factory-established standard frequencies (see Standard Frequency Table, page 21). These have been calculated to minimize interaction. The particular frequency selection depends on

- the number of channels in a system, and
- the number of channels to be used simultaneously. If in doubt, ask the factory to recommend frequencies for your system.

Simultaneous Operation

Multiple signals can be transmitted and decoded simultaneously, with the decoders consisting of either single or multi-channel resonant reed relays. Out of a very complex signal, each reed will respond to its respective frequency. Reliable simultaneous operation can best be achieved by taking steps to minimize interaction of frequencies. Follow these recommendations:

- Select specific frequencies that have the least possible interaction.
- Keep individual tone distortion below 5 percent.
- Keep individual tone amplitudes at relatively uniform levels.

There may still be beat frequencies present that will cause individual reed amplitudes to pulsate. A larger integrating capacitor to increase the switching time constant will ordinarily prevent the reed pulsation from causing intermittent output.

STANDARD FREQUENCY TABLE

The frequencies listed below have been established to allow adequate separation and minimum harmonic relationship for use in multiple frequency systems.

FREQ. CPS	EIA CODE	FREQ. CPS	EIA CODE	FREQ. CPS	EIA CODE
67.0	L 1	258.8	136	651.9	153
71.9	L 2	266.0	106	669.9	123
77.0	L 3	273.3	137	688.3	154
82.5	L 4	280.8	107	707.3	124
88.5	L 4A	288.5	138	726.8	155
94.8	L 5	296.5	108	746.8	125
100.0	1	304.7	139	767.4	156
103.5	1A	313.0	109	788.5	126
107.2	1B	321.7	140	810.2	157
110.9	2	330.5	110	832.5	127
114.8	2A	339.6	141	855.2	158
118.8	2B	349.0	111	879.0	128
123.0	3	358.6	142	903.0	159
127.3	3A	368.5	112	928.1	129
131.8	3B	378.6	143	953.7	160
136.5	4	389.0	113	979.9	130
141.3	4A	399.8	144	1006.9	161
146.2	4B	410.8	114	1049.6	131
151.4	5	422.1	145	1084.0	P
156.7	5A	433.7	115	1120.0	S11
162.2	5B	445.7	146	1190.0	S12
167.9	6	457.9	116	1220.0	S2
173.8	6A	470.5	147	1265.0	S14
179.9	6B	483.5	117	1291.4	S3
186.2	7	496.8	148	1320.0	S15
192.8	7A	510.5	118	1355.0	S16
203.5	M1	524.6	149	1400.0	S17
210.7	M2	539.0	119	1430.5	S7
218.1	M3	553.9	150	1450.0	S18
225.7	M4	569.1	120	1500.0	S20
233.6	M5	582.1	H	1520.0	S9
241.8	M6	600.9	121	1550.0	S21
250.3	M7	617.4	152	1600.0	S22
		634.5	122		

MODEL	RECOMMENDED RANGE CPS	TOTAL RANGE CPS
RD 10, RE 10	67-300 (39)	67-1600 (100)
RD 1, RE 1	300-600 (25)	300-1600 (61)
RD 5	200-600 (38)	100-1000 (77)
RD 7	150-500 (40)	150-700 (52)

Figures in parentheses are the number of standard frequencies possible within the listed range. Use the frequencies in the "Recommended Range" column for optimum performance.

Impedance Matching

Because resonant reed relays operate on extremely low power levels, the power loss resulting from even a gross impedance mismatch is usually negligible. The normal practice is to specify a DC coil resistance that provides the desired impedance at the mid-frequency of the total range being used. Impedance is approximately two times the DC resistance at 400 cps.

Drive Level

In designing a tone control system it is best to provide enough power to establish a normal operating level at (or slightly above) the specified operating level of the resonant reed. If the power falls below the specified operating level, the bandwidth is reduced and operation becomes marginal. Good amplifier design should incorporate AGC, limiting, or clipping to prevent overdriving the reed and, at the same time, have enough gain to amplify the most sensitive signals to the normal operating level of the decoder. (See figure 24, page 35).

Extraneous Magnetic Fields

The calibration of a resonant reed relay depends on, among other things, a built-in permanent magnet bias. External magnetic fields and materials that change the established bias level will affect the frequency and sensitivity calibration. Shielding can protect against external magnetic fields, but this is seldom necessary if good engineering practices are followed in laying out the assembly.

Decoder Response Time

Typical response time for a decoder reed to make initial contact closure is 50 milliseconds. It is important to allow additional response time for the integration of the secondary switch circuit. The time constant is calculated by the formula

$$TC = R_1 C \left(\frac{100}{\text{duty cycle \%}} \right)$$

C is the value of the integrating capacitor and R_1 is the value of the series limiting resistor.

Encoder Start Time

Because resonant reeds operate in relatively low frequency ranges, the natural build-up time to maximum amplitude is relatively slow. Commonly used transistor encoder circuits will require up to 60 seconds to build up to maximum output. To obtain immediate frequency transmission, run the encoder circuit continuously and key the output to the amplifier or line.

Encoder Frequency Calibration

A reed should always be tuned in the same encoder circuit in which it is to be used. If operated at an amplitude level different from the tuning circuit, the frequency will deviate. Standard Bramco units are tuned in the recommended encoder circuit shown in Figure 7, page 7. Because feedback affects reed amplitude, the reed should also be calibrated with the circuit adjusted to the specified output (or feedback) level.

Encoder Impedance Matching

When designing encoders into systems using simultaneous tones, be sure to high impedance mix as illustrated in Figure 14. To determine the approximate value of the resistor in each leg, multiply the value of the transformer primary by the number of frequencies to be transmitted simultaneously. The transformer primary must be used (the nearest standard value to 60K).

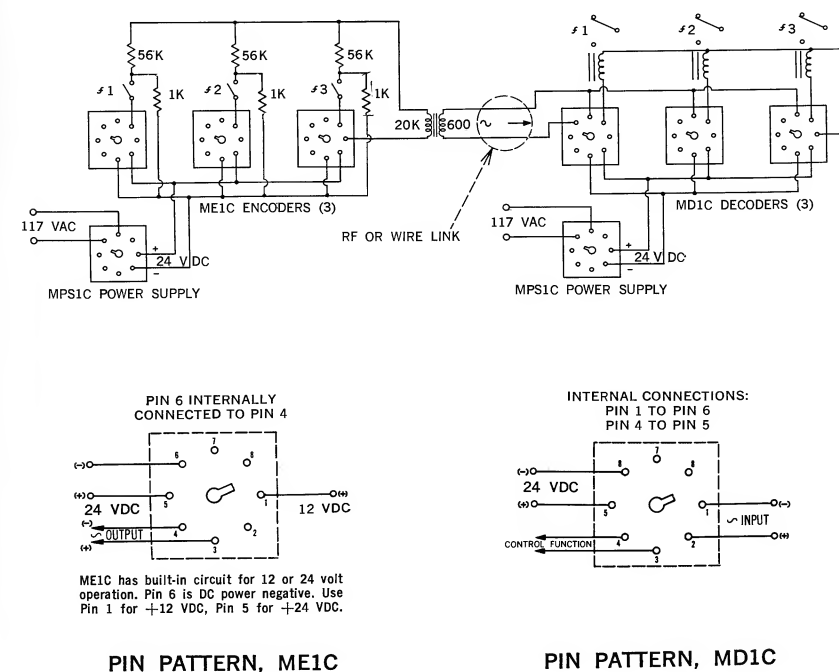


FIGURE 14. TYPICAL ENCODER-DECODER MODULE WIRING DIAGRAM

SECTION II. SCHEMATIC DIAGRAMS

In the broad spectrum of control applications, resonant reeds are used today to control, select, command, regulate, supervise and indicate. This section shows just some of the many ways in which resonant reeds have been successfully designed into control circuits. The diagrams that follow are mainly intended to stimulate ideas for solutions to similar control problems. Some are quite simple. Others were developed only after long working relationships with control engineers who had specific problems to solve.

If you have a control application, and you don't find the answer here, Bramco engineers invite you to write or call.

NOTE: Throughout this section, references are made to specific Bramco resonant reed products (RE1, RE10, ME1C, RD1, RD5, RD7, RD10, and MD1C). Brief descriptions of these products are provided on page 62 and will be helpful in more fully explaining the type of reed product around which each schematic diagram has been designed.

figure 15. resonant reed stabilized oscillator circuit

This is a feedback oscillator in which there are two feedback paths. One path C1-R1-R2 controls amplifier gain. The other path C2-R3 provides a return signal to the reed coil to sustain oscillation. Random noise starts reed oscillation which causes inductive swing which is amplified by T1 and T2. Output of T2 is applied to variable resistance element (bulb TS 1860) which varies the amount of emitter by-passing and therefore varies the gain of T2 and T1 (via R4-D1 path). The output is R-C coupled to T3 emitter follower stage which provides low impedance (600 ohm approximately) output. Note the emitter follower is used because it does not load down the oscillator and it provides a low impedance output without normal inherent transformer losses.

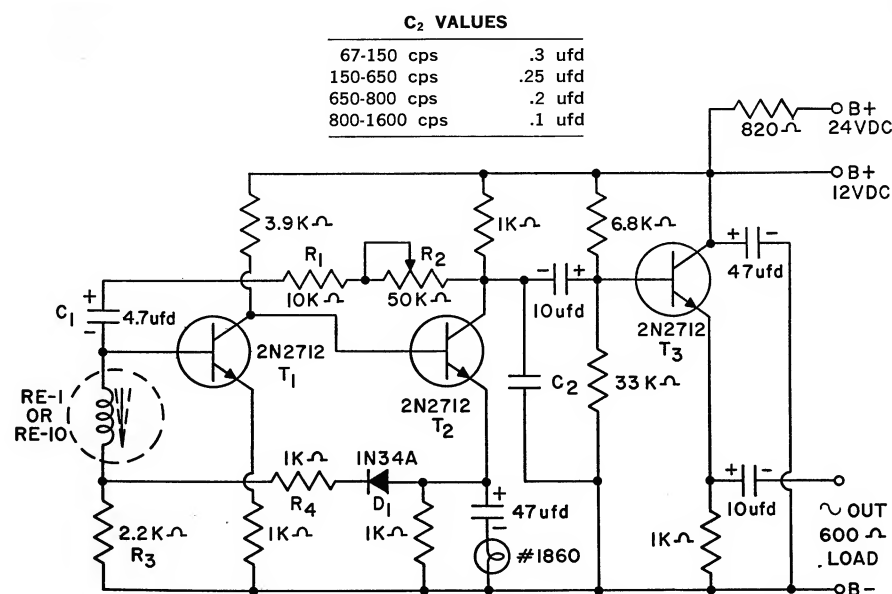
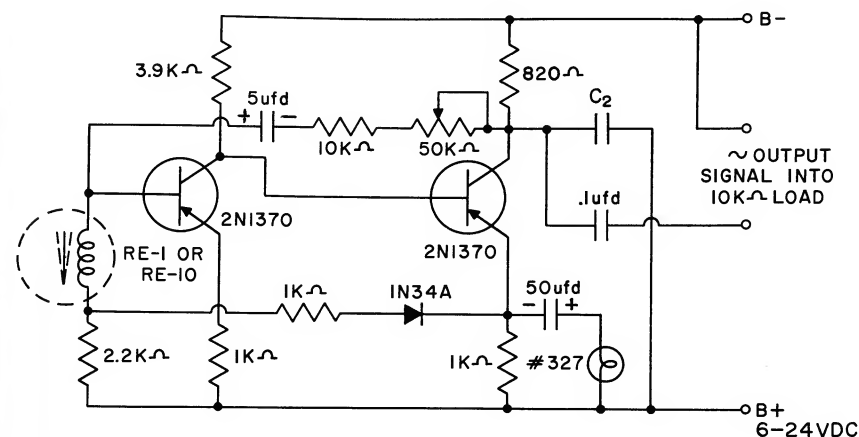


figure 16. germanium oscillator with high impedance output

Figure 16 is similar to figure 15 but the emitter follower stage has been omitted to provide a higher impedance output. It uses low cost germanium PNP transistors and will operate over an input voltage range of 6 to 24 vdc.



C ₂ VALUES	
67-150 cps	.3 ufd
150-650 cps	.25 ufd
650-800 cps	.2 ufd
800-1600 cps	.1 ufd

figure 16a. silicon oscillator with high impedance output

Figure 16a is the same oscillator circuit as figure 15 but the emitter follower stage has been omitted to provide a higher impedance output.

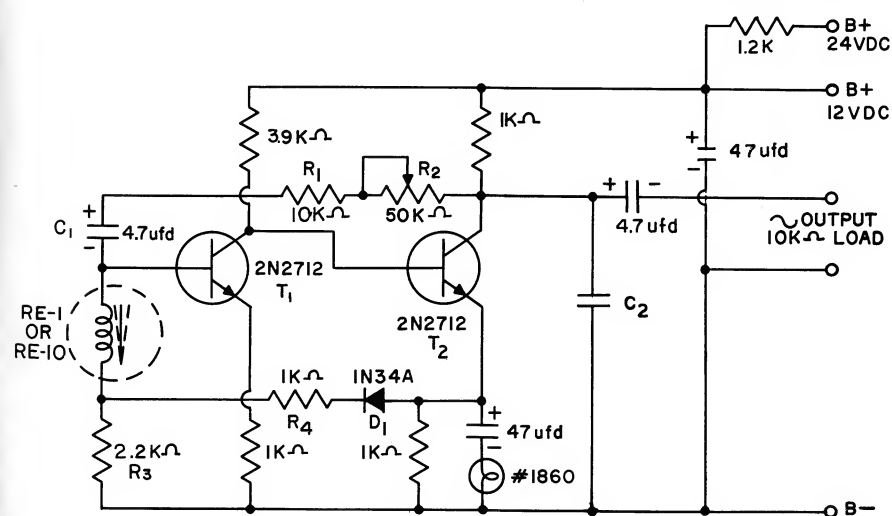
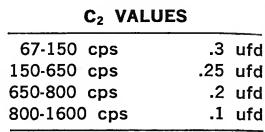


Figure 17 is the same as figure 16 but a matching transformer is used to provide a 600 ohm output.



This circuit is basically a two-stage amplifier with two feedback paths and a resonant reed oscillator to stabilize the frequency of the circuit. Circuit noise is amplified by V1 and V2 and applied to the coil of the reed oscillator through R1. This causes slight reed motion, inducing an AC signal in the coil which is then fed to the grid of V1. The AC signal continues to be amplified and fed back until it builds up to a level that is controlled by the feedback system. One feedback loop, R1-C1, feeds the resonant reed oscillator coil and the grid of the first amplifier stage. The other loop, C2-C3, connects the output of the second amplifier stage back to its own grid. The sine wave output can be adjusted by attenuator R2. This circuit is designed for frequencies up to 300 cps.

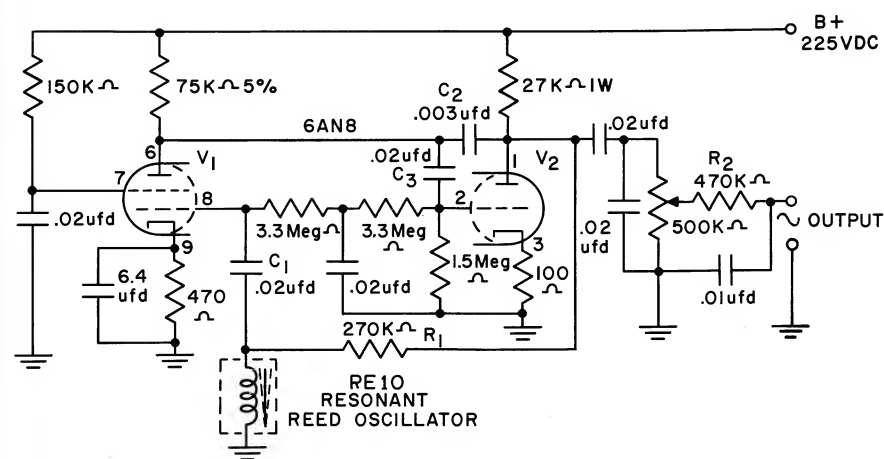


figure 19. multi-reed capacitance encoder circuit

This oscillator consists of an amplifier with a cathode follower driving a resonant reed relay. Each reed has a capacitance pick-up which is switch selected and fed through a feedback path to the amplifier input to cause oscillation. The oscillation is sustained by an AGC network.

Random circuit noise is amplified by V1 and coupled to a special resonant reed encoder by way of V2. The amplified noise causes slight vibration of the resonant reeds. One of the resonant reeds has its capacitance pick-up switched to the input of V1 by a rotary selector switch to complete a circular path for oscillation. The amplitude of oscillation is controlled and stabilized by D1 and C1. (Note: The amplitude is not great enough to cause the reed to come in contact with the capacitance pick-up.) Any one of four resonant reed capacitance pick-ups may be switch selected to provide one of four output frequencies.

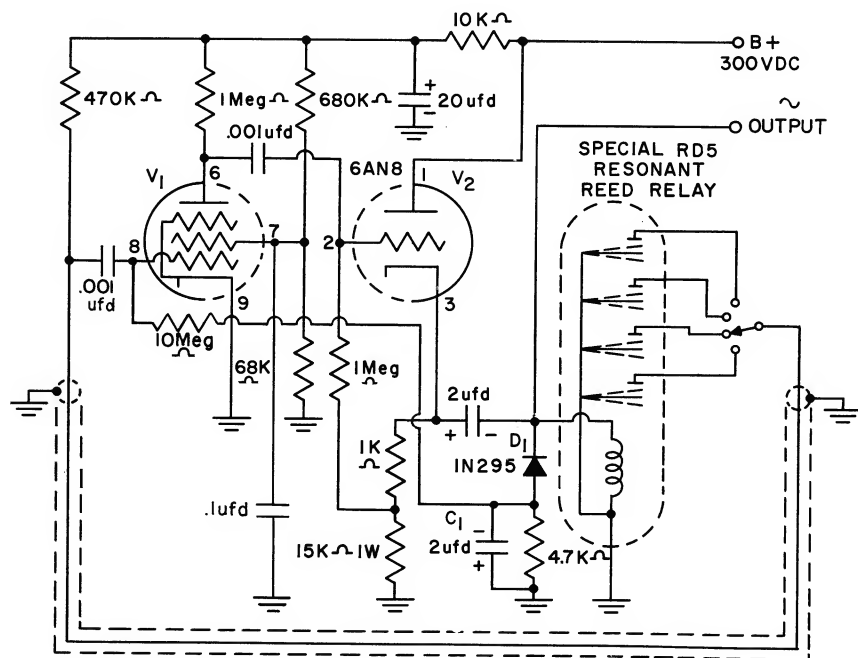


figure 20. single tone pulsed encoder

The circuit is an audio amplifier with clipping to control the output level which is adjustable by R1. When S1 is closed a DC pulse is applied to the RE1 by means of C1, causing a physical vibration of the reed. This vibration generates a signal in the coil of the RE1. The output signal is generated by the reed-affected magnetic fluctuation in the vicinity of the pickup coil. The generated tone is then amplified by T1, clipped by T2, and connected to the output terminal by means of C2.

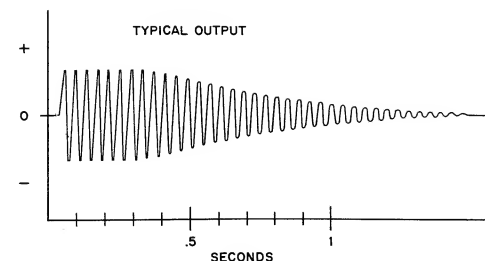
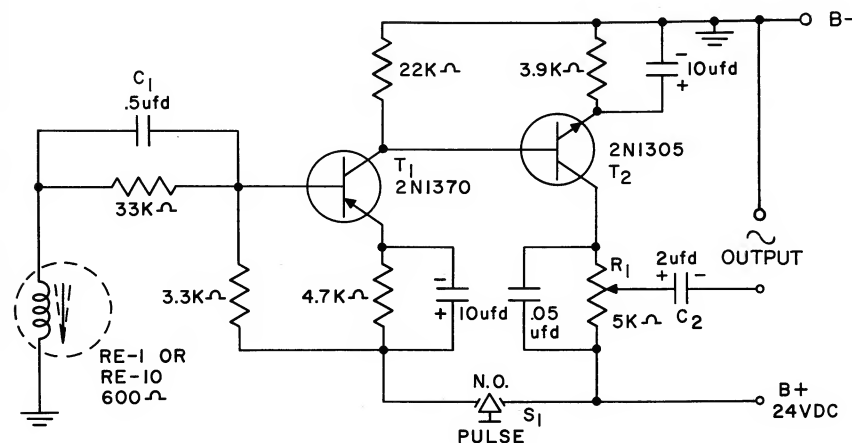


figure 21. two-tone sequential pulsed encoder

The encoder provides a two tone sequential output and transmitter keying in preset timed intervals.

Section I is the primary timing circuit. When S1 is switched, RLY1 keys the transmitter, enables timing Section II and encoding Section III, and connects the output of Section III to the audio output terminal. C1 holds RLY1 in until the entire sequence is completed. When RLY1 drops out, the previously closed circuits are opened and contact B bleeds C2 to recycle the secondary timing (Section II). Contact C connects C3 to charge it for the next operation of the primary timing circuit. The R1-C3 time constant provides a guard interval between tone codes.

Section II is the secondary timing circuit. When contact B is opened and C is closed (Section I) the R2-C2 time constant provides the delay before gating the 3N58 switch which pulls in RLY2. When RLY2 pulls in the second frequency RE1 is substituted for the first frequency RE1 (Section IV).

Section III is an audio amplifier stage with clipping to control the output level which is adjustable by R3. When contact C (Section I) is closed, a DC pulse is applied to the first RE1 by means of C4. This generates a signal in the RE1 coil due to the pulsed vibration of the reed. The signal is amplified by T1, clipped by T2, and connected to the output terminal by contact D (Section I). When RLY2 operates the second RE1 is switched into Section III. The switching action causes this RE1 to be DC pulsed and amplified.

Section IV consists of a bank of single channel resonant reed encoders. Any number of reeds can be switch selected to program any desired frequency code into the first and second RE1 locations.

This encoder is compatible with the decoder shown in Figure 36.

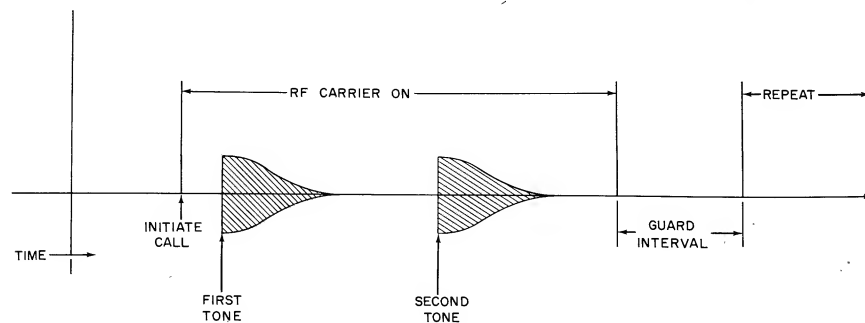


figure 21

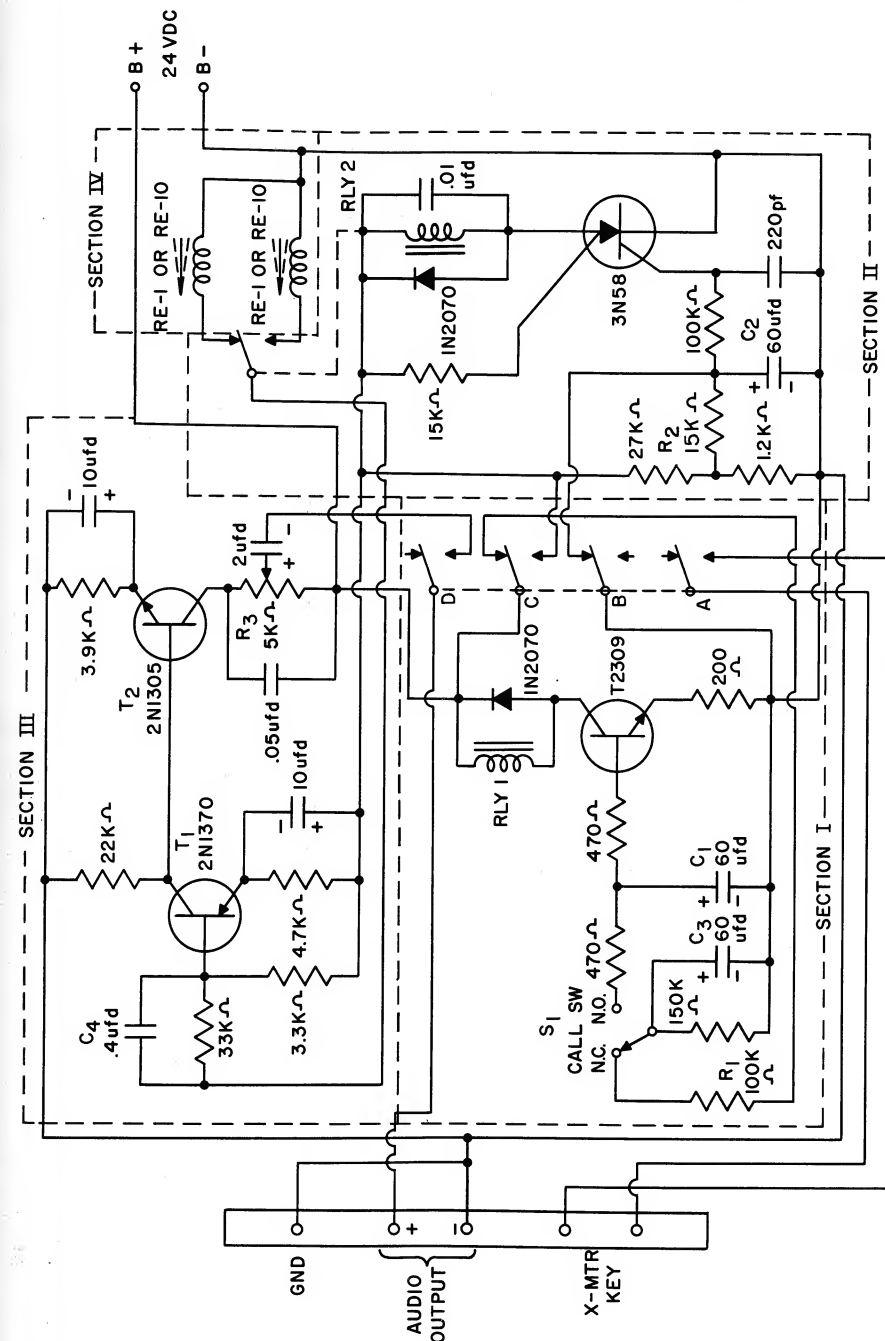


figure 22. LC oscillator circuit—transistor type

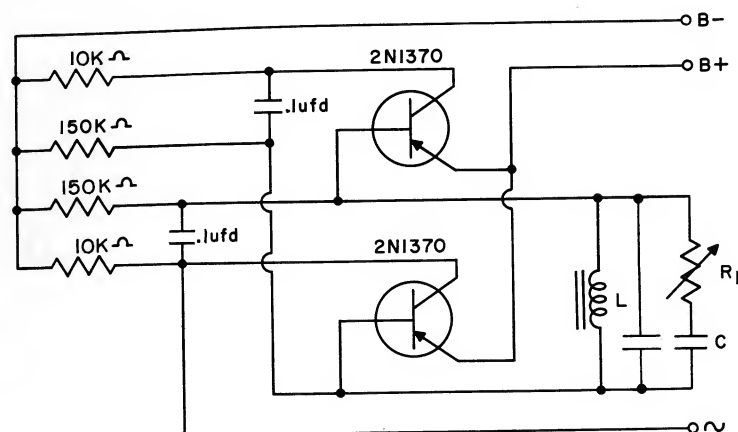
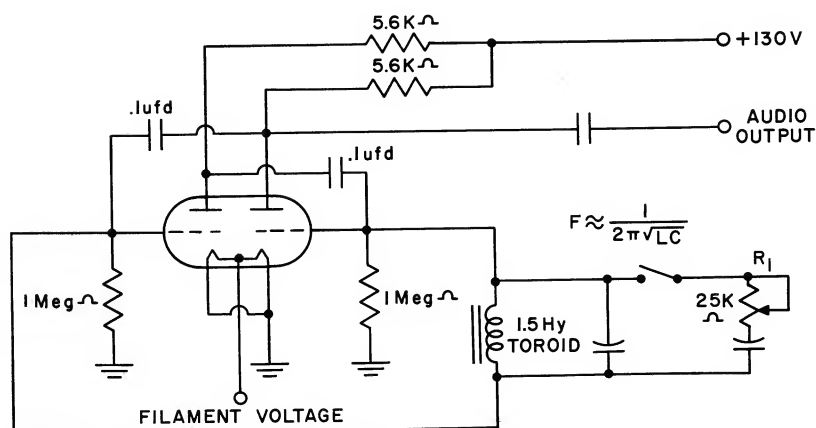


figure 23. LC oscillator circuit—tube type



Both the transistor and tube circuits shown are a form of a multi-vibrator, with the frequency controlled by an LC parallel resonant tank circuit. The frequency may be shifted a few cycles by the adjustment of R1.

figure 24. transistor decoder circuit

The front end is a two stage amplifier having a high impedance input. It operates as a linear amplifier (low distortion) in the 0 - 2 VRMS input range. Above 2 VRMS the amplifier clips and provides a constant amplitude signal output to the reed coil for inputs up to 5 VRMS. When the proper predetermined frequency is received, the reed vibrates causing intermittent contact closure. The closure is integrated by R1-C1 and causes T3 to conduct, providing a constant DC voltage output across the external load. When the input signal level is between 1.5 and 2 VRMS the bandwidth of each reed will be proportional to the input level. When the input is between 2 and 5 VRMS the bandwidth of each reed is essentially constant. The output rating is 50 ma maximum.

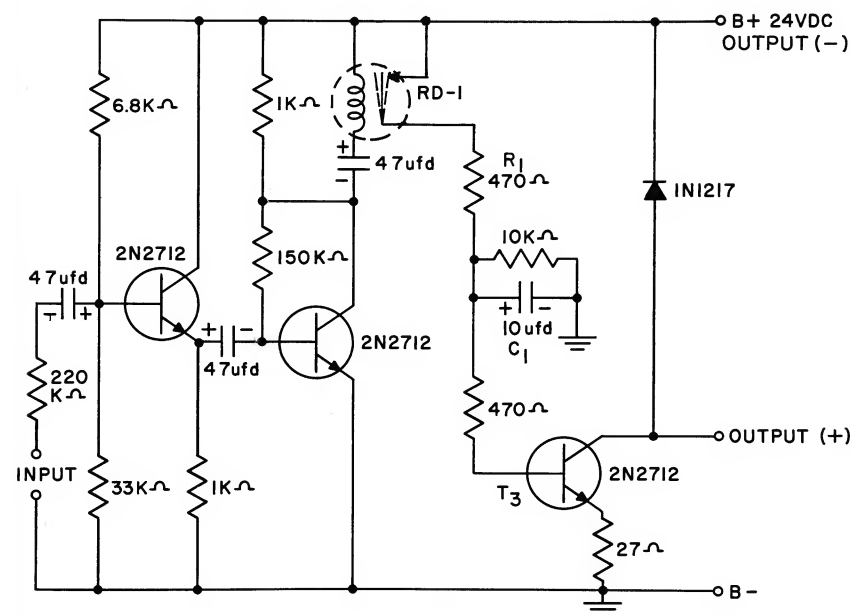


figure 25. five channel decoder circuit

Figure 25 is the same circuit as figure 24, but a five channel resonant reed relay is used with five individual transistor switch circuits.

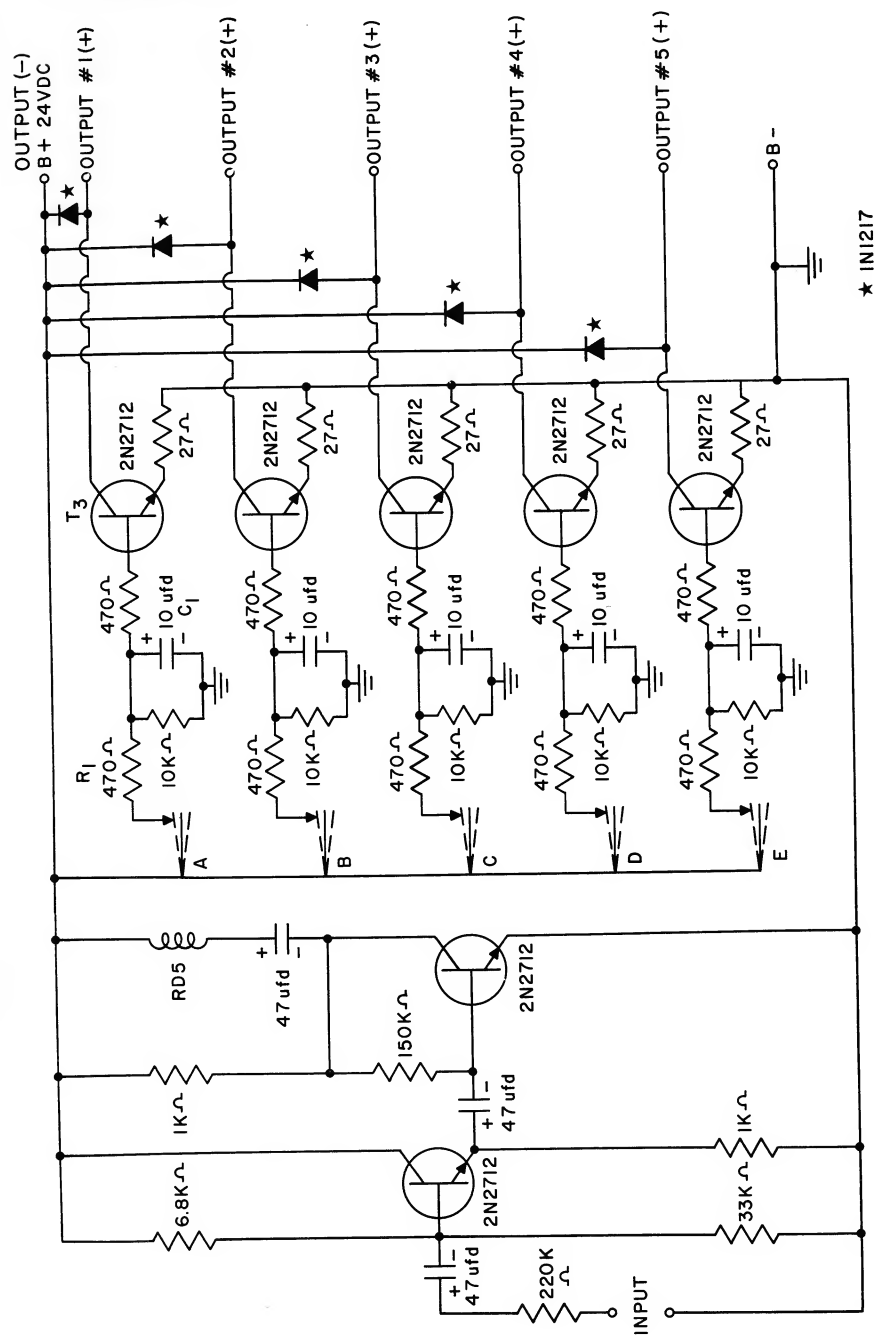


figure 26. push-pull audio amplifier

This amplifier has the capability of driving approximately 10 single channel resonant reed relays. Input impedance is about 15K. It is a general purpose amplifier that uses three identical low cost transistors. The secondary impedance of the output transformer should be matched to the combined parallel impedance of the resonant reed relays.

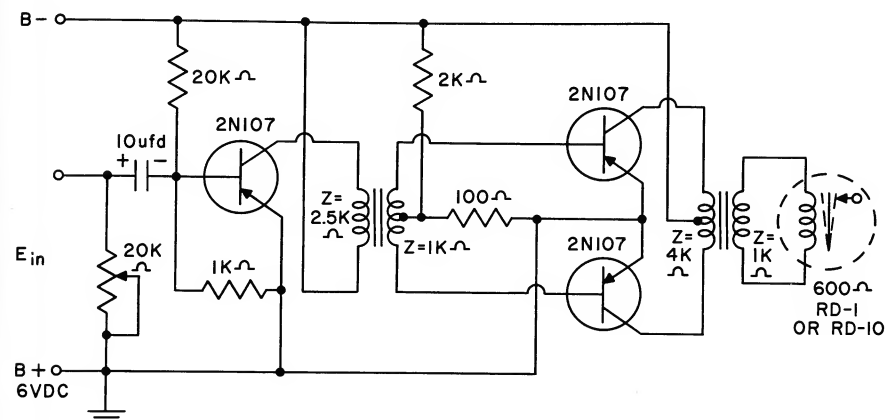


figure 27. tube type amplifier circuit

A single tube amplifier circuit having a capability of driving up to 20 resonant reed relays. It has a high impedance input that is essentially constant due to the "buffer" action of the tube. The output transformer (T1) secondary must be impedance matched to the combined impedance of the resonant reed relay coils that are connected in parallel.

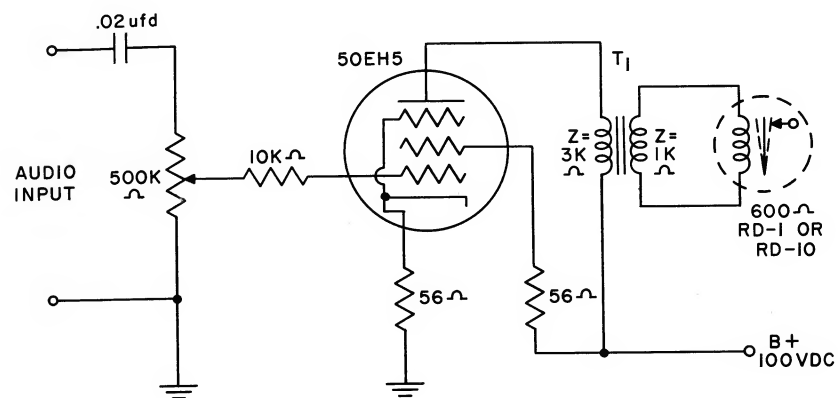


figure 28. secondary relay switch circuit

When the reed contacts close intermittently the 2 mfd capacitor charges through the 6.8K current limiting resistor. The capacitor integrates the low level of pulsating DC and holds in the sensitive secondary relay to provide a continuously closed circuit at the normally open contact.

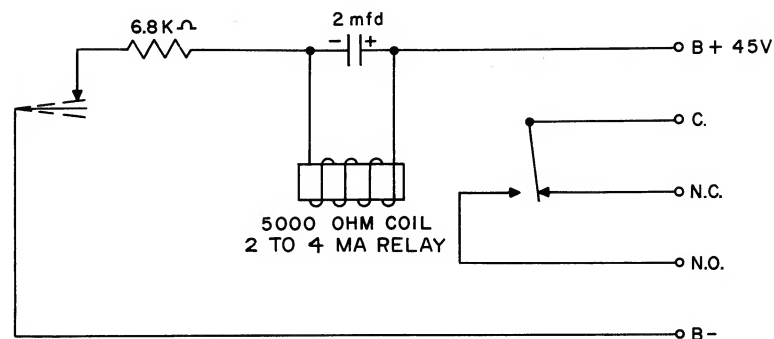


figure 29. latching switch circuit

The transistor is biased to cut-off. When the reed contacts close intermittently, the duty cycle is integrated by the R1-C1 network until the voltage across C1 causes the transistor to conduct, pulling in the secondary relay. The diode eliminates the inductive spike generated by the relay coil, protecting the transistor. After contact transfer the bottom set of contacts holds relay closed. The relay can be returned to its normally open state by removal of B+ (S1). R3 bleeds off C1 after reed stops so that the transistor will be non-conducting when the circuit is unlatched.

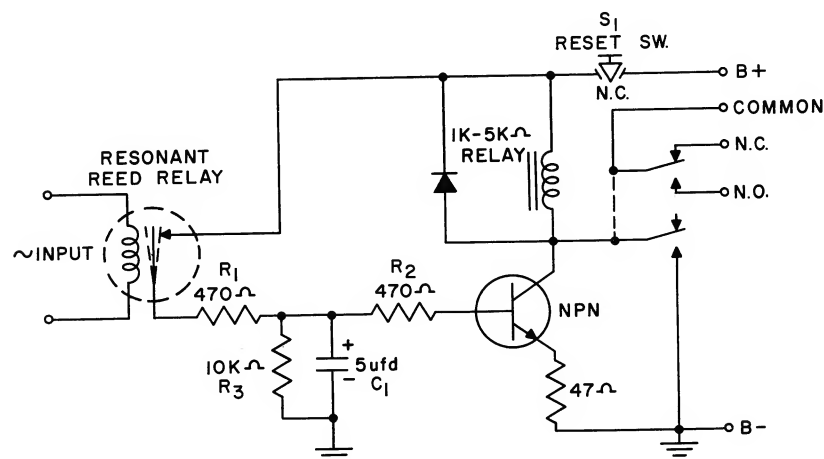


figure 30. timed latching switch circuit

The transistor is biased to cut-off. When the reed contacts close intermittently, the duty cycle is integrated by the R1-C2 network and C1 is discharged through R1-C1 network causing transistor to conduct, closing the secondary relay. When reed stops vibrating, the transistor remains in conduction until C1 again charges up to the transistor cut-off point. At this time the transistor stops conducting and the secondary relay drops out. The lock-up time as determined by C1 is approximately five to ten seconds for a 100 mfd value. The diode protects the transistor from inductive spikes.

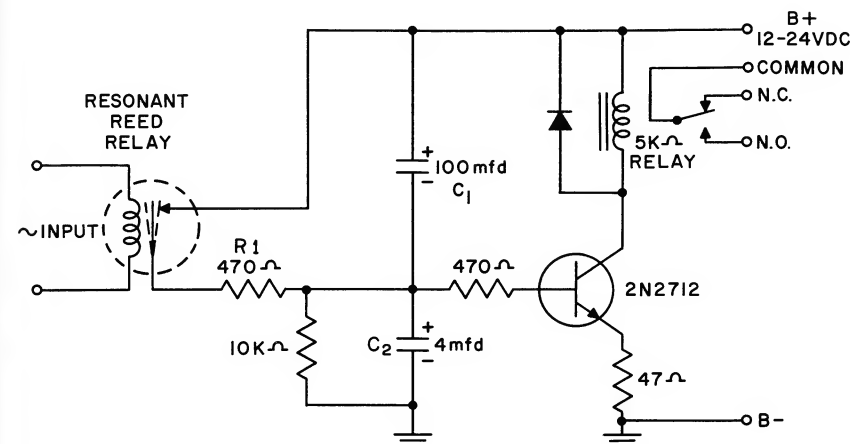


figure 31. stepping switch circuit

When the reed relay contacts close intermittently, C1 discharges until the transistor conducts, stepping the relay. R1 limits the resonant reed relay contact current. When the reed stops vibrating, the capacitor charges to B+ potential and biases the transistor to cut-off. R2 limits the resonant reed relay contact current (from B+) and limits the transistor from going too far into saturation when C1 is fully discharged. Each successive operation of the reed relay contacts will step the stepping relay one position. The diode protects the transistor from the inductive spike of the relay coil.

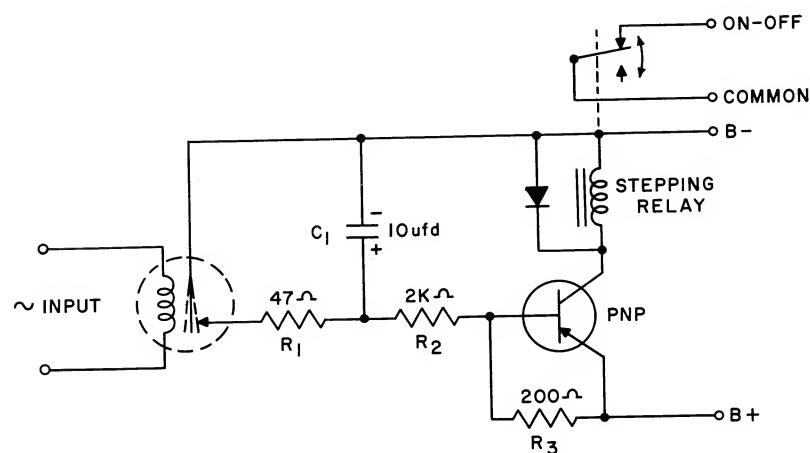


figure 32. tube type decoder switch circuit

The tube is biased to cut-off. When the reed contacts close intermittently the duty cycle is integrated by the R1-C1 network until the voltage across C1 causes the tube to conduct, pulling in the secondary relay. R2 and R3 bleed off C1 after the reed stops vibrating so the tube will return to its non-conducting state. R1 limits the resonant reed relay contact current. R1-C1 values are also selected to control the desired secondary relay pull-in time constant.

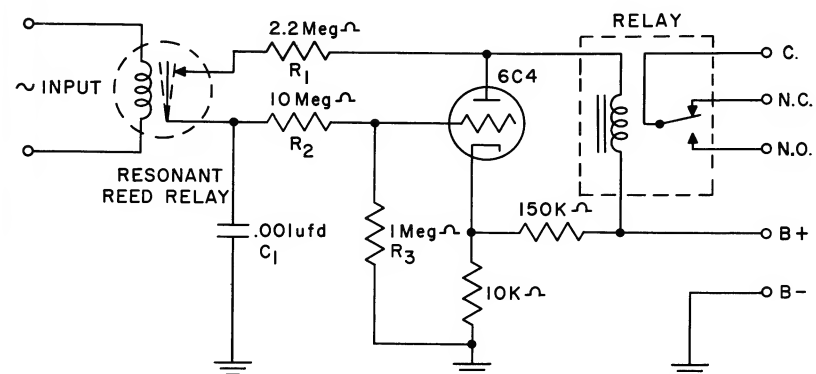


figure 33. neon lamp indicator

Reed contacts close intermittently and charge the .3 mfd capacitor to the threshold voltage (slightly less than 100 VDC) of the neon lamp. R1 bleeds off the capacitor after closure stops. It also acts as the limiter for the neon lamp.

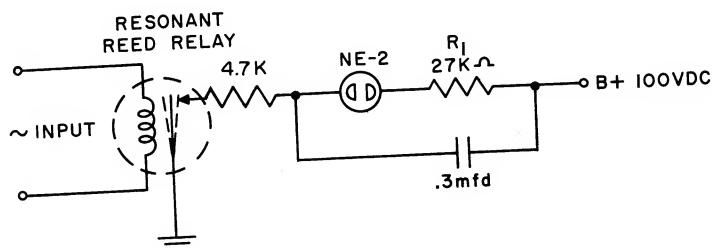


figure 34. incandescent light switch

When reed contacts close, Capacitor C and resistor R1 integrate the duty cycle and cause the transistor to conduct, lighting the light bulb. The bulb remains on as long as the reed contacts make intermittent closure. When closure stops, R3 bleeds off C and the transistor and bulb revert to the normally off mode.

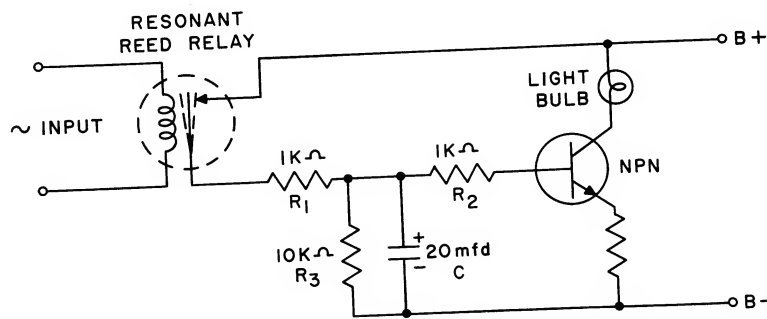


figure 35. two-tone sequential switch circuit

This is a simple 2 frequency decoder circuit. When the first frequency is received the 25 mfd capacitor is charged. When the second frequency is received the charge is transferred to a tube grid or transistor base that switches the desired control function. The .4 megohm resistor bleeds the capacitor to prevent undesired codes from activating the function.

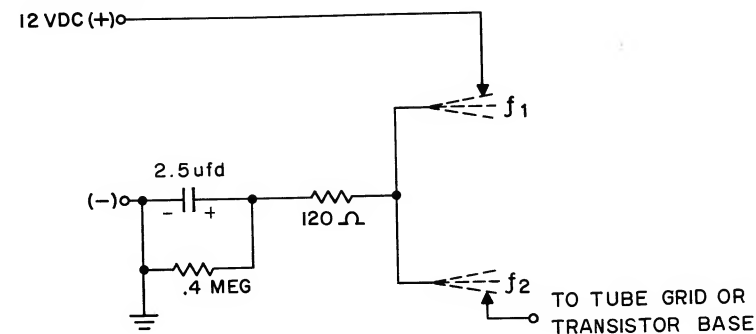
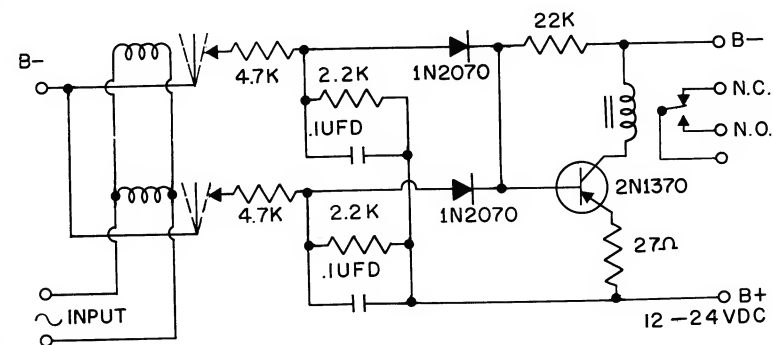


figure 35a. two-tone simultaneous switch circuit

This circuit is essentially an AND logic network. The transistor is held in the cutoff region by the two diodes which are forward biased when the reeds are not operating.

When both resonant reeds vibrate, both diodes are reverse biased and they become high resistance elements. This forward biases the transistor, pulling in the relay. If only one of the resonant reeds is activated then one of the diodes remains in the forward biased condition and the transistor switch remains off.



The decoder can be programed to any one of twenty two-tone sequential codes by wiring first tone feed to any terminal 1 through 5 and the second tone feed to any remaining terminal. The audio input is fed by a 3.2 ohm impedance audio source (speaker transformer). B1, R5, D1, and D2 form a drive limiter circuit to limit the maximum signal to the resonant reed relay coil. When the first predetermined tone is received, the reed vibrates and the contact closure charges C1. This charge is held for a limited length of time. If the second reed of the two tone sequential code operates within this limited time, the charge on C1 is transferred to C2. The charge on C2 gates the silicon controlled switch (3N58) causing RLY1 to pull in. D3 protects the 3N58 from inductive spikes from RLY1. The 3N58 will remain in conduction and hold in RLY1 until B+ is removed. When RLY1 is pulled in one set of contacts will transfer the audio input from the resonant reed relay coil to the speaker. The second set of contacts provides an external switching function. The third set of contacts turns on the call light until RLY1 is reset.

Ten (or two five-channel) resonant reed relays selectively control a Ledex stepping switch to any one of ten positions. When a predetermined tone is present, the reed contacts are integrated and pull in the secondary relay. As long as the secondary relay is closed, the selector will self step until the appropriate rotor notch is positioned to break the reed contact circuit. Note only one secondary relay is used for all ten reeds. As many as nine switching decks can be ganged on the stepping switch to provide a total of nine circuits with ten positions.

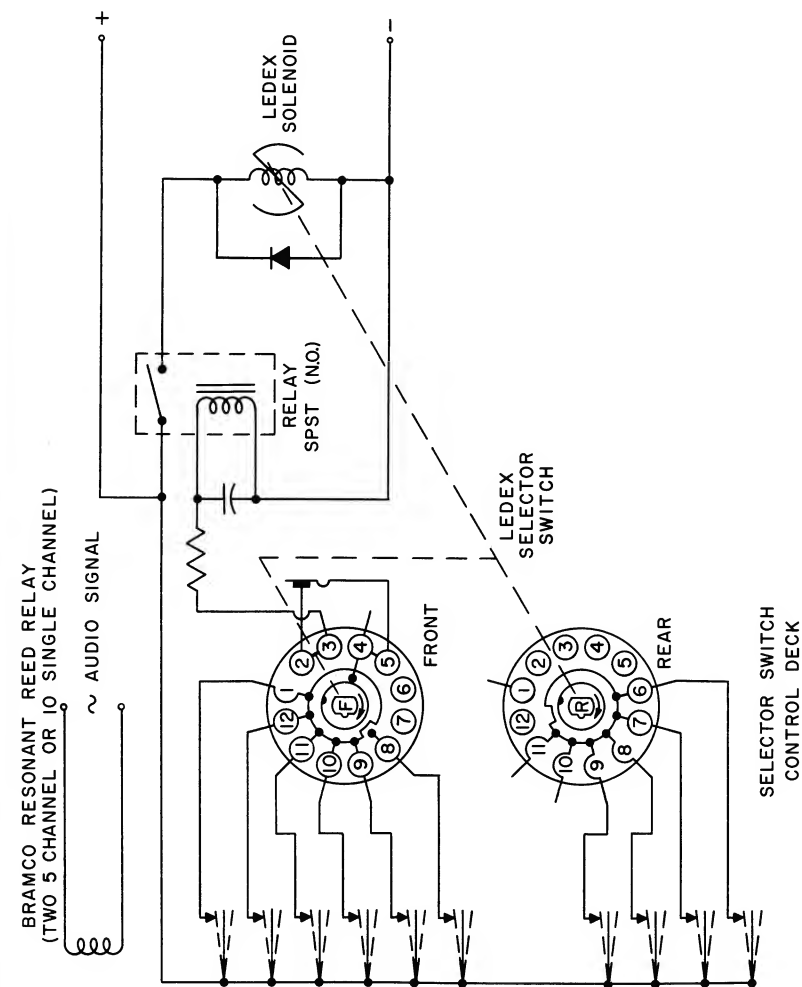


figure 38. five-tone selective ten-position stepping switch

Five (or one five-channel) resonant reed relays selectively control a Ledex stepping switch to any one of ten positions. The logic of the selector switch deck provides for a two-tone simultaneous code to step the switch to the selected position. When two tones are present, both reed contacts will be integrated and pull in the secondary relay. As long as the secondary relay is closed the selector will self step until the rotor notches are positioned to break both reed contact circuits. Note that only one secondary relay is used for all five reeds. As many as nine switching decks can be ganged on the stepping switch to provide a total of nine circuits with ten positions.

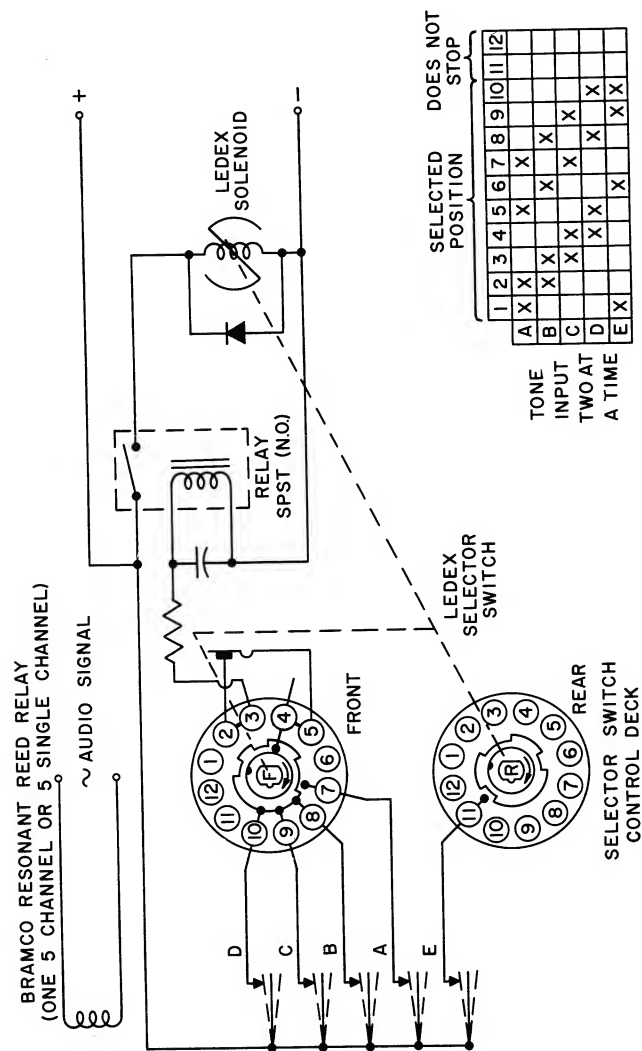


figure 39. 28-function relay tree

Relays A through H are controlled by eight resonant reed relays (or two 4 channel relays) tuned to eight individual frequencies. When any two of the eight frequencies are transmitted simultaneously, the two predetermined resonant reed relays will pull in the appropriate secondary relays. The tree acts as an AND gate to the two-tone coded input, providing 28 selective outputs (AB through GH) only when two tones are present. Note if only one tone is received, eight additional outputs A through H are possible.

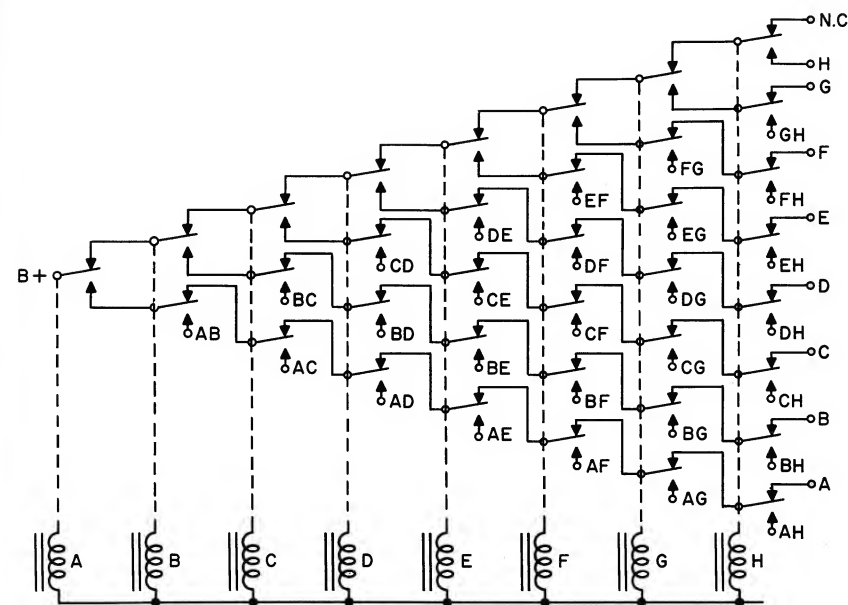


figure 39a. five-tone 10-function logic circuit

With only 5 inputs, taken two at a time, this circuit will control 10 separate functions. The inputs are controlled by 5 frequency selective circuits as in figure 25. When any two frequency signals are received simultaneously, the corresponding output function is activated as indicated in the chart.

The 10 control relays, each with 2 diodes in parallel, are connected across 24 vdc through 2.2 K resistors. The diodes hold the coil voltage to .5 vdc. When one of the appropriate secondary relays is energized, the polarity on one diode is changed. This reverse biases the diode, causing it to become a high resistance. Each control relay still has at least one diode shorting it. When another secondary relay is energized, a second diode is reverse biased, removing the short from the desired control relay, causing it to pull in.

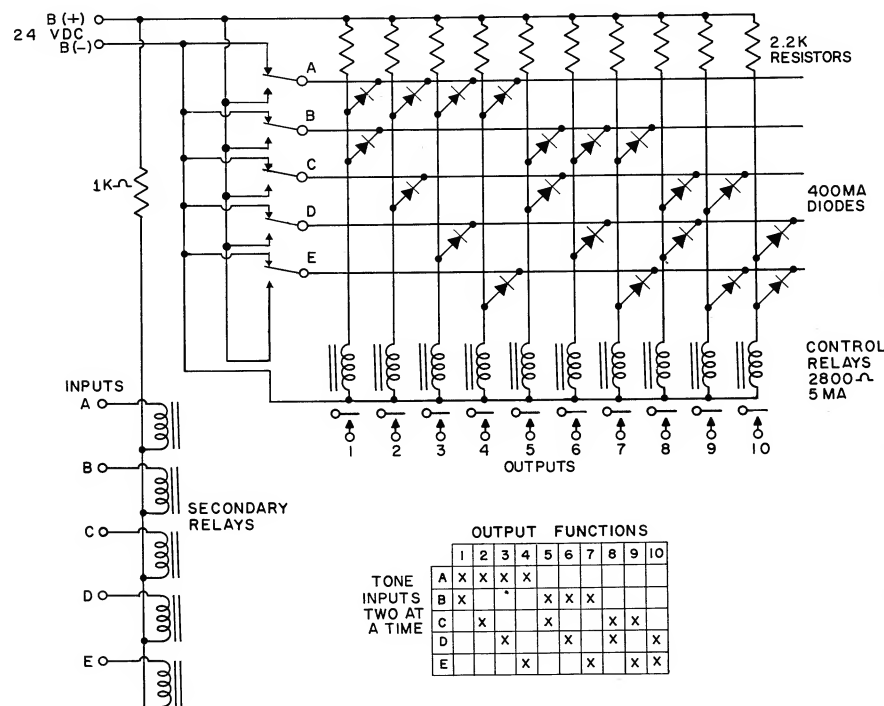


figure 40. frequency divider circuit

The prime purpose of the divider is to reduce high frequency audio tones down to the audio spectrum of the resonant reed relay. This is essentially a bi-stable multi-vibrator with an emitter-follower output stage to drive a resonant reed relay. Output is one-half of the input frequency and the circuit gain is approximately unity.

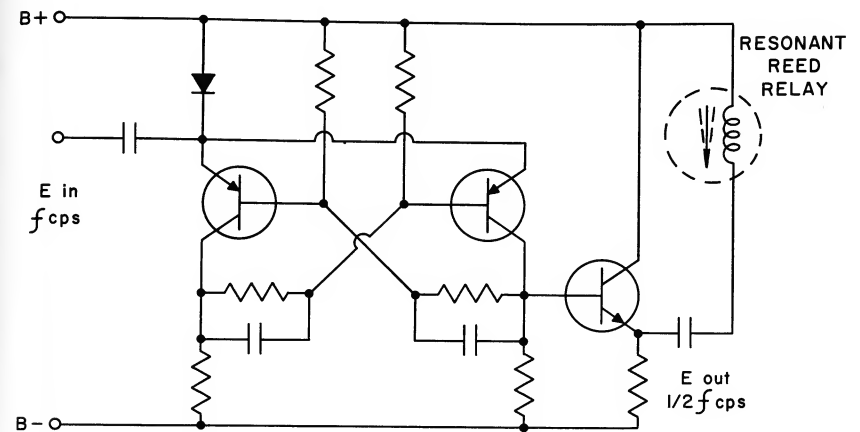


figure 41. frequency multiplier

The prime purpose of the multiplier is to increase low frequency audio tones up to the audio spectrum of the resonant reed relay. This is essentially an amplifier with its output parallel resonated at the first harmonic of the input frequency. C2 is the output coupling capacitor which also filters out the fundamental frequency. Output frequency is twice the input frequency. The circuit has a low input impedance and a high output impedance.

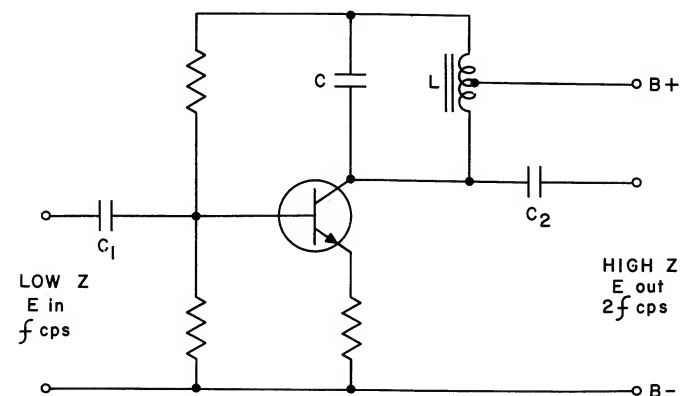


figure 42. 27 mc tone transmitter

This circuit consists of a relaxation oscillator which controls the frequency of a multi-vibrator and modulates a 27 mc RF generator. T1 is a unijunction transistor. This transistor generates a frequency which is controlled by the R1-C1 time constant. The generated signal gates the multivibrator (T2, T3). The signal then gates T4 to modulate the RF generator at an audio rate. The RF generator is a 20 mw, third overtone, 27 mc crystal controlled oscillator.

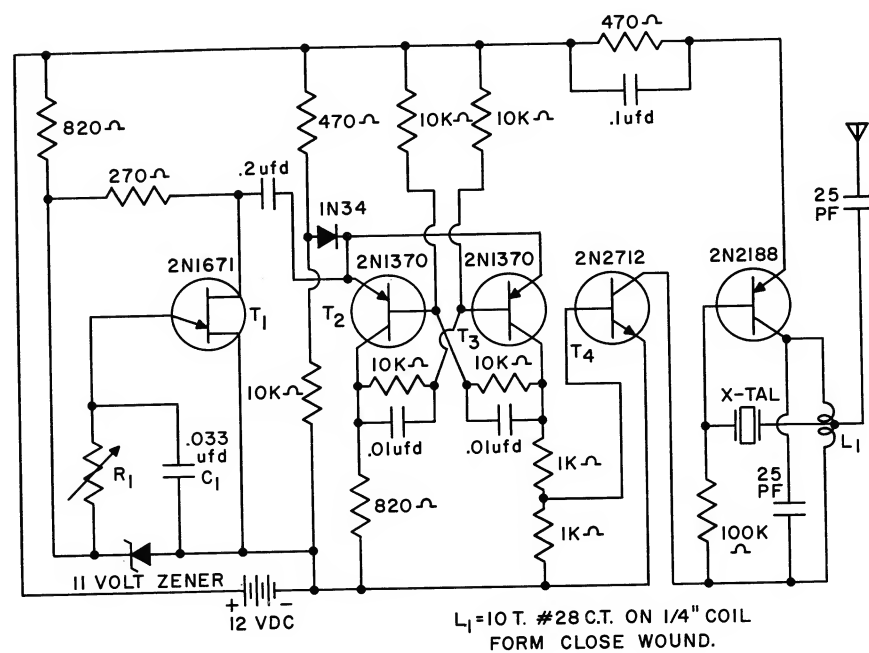
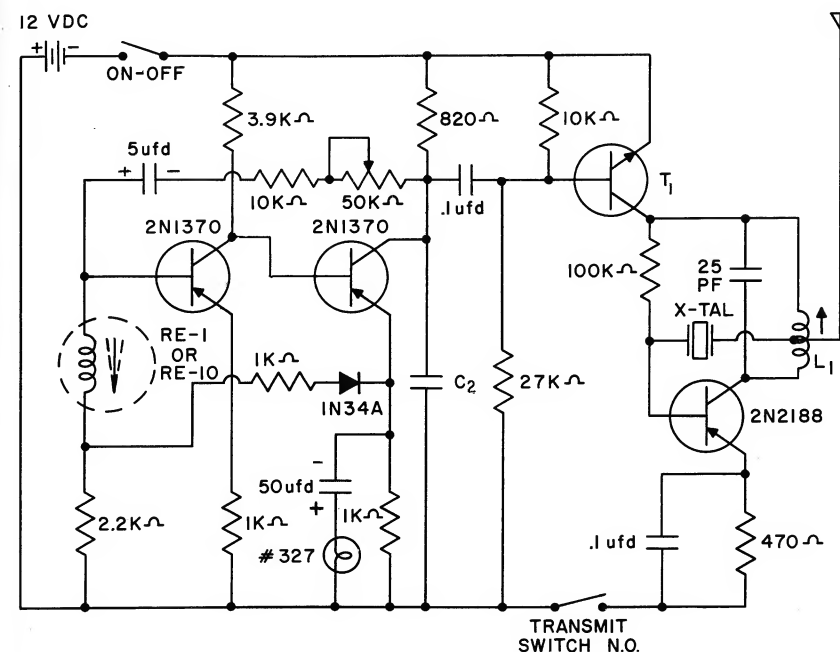


figure 43. reed stabilized tone transmitter

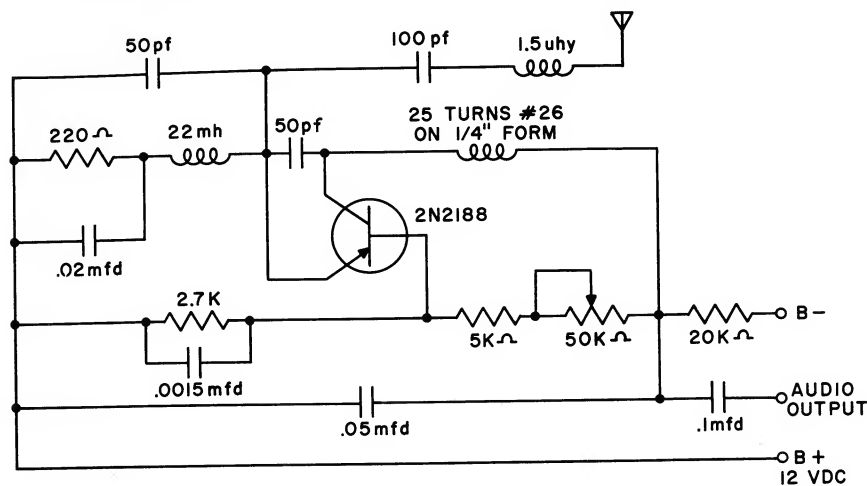
Reed oscillator circuit operates as described under figure 15. T1 operates as a variable DC feed to the RF section. The audio signal from the reed oscillator causes the DC feed to vary and modulate the RF carrier at the audio rate. The RF section is a 20 mw third overtone 27 mc crystal controlled oscillator.



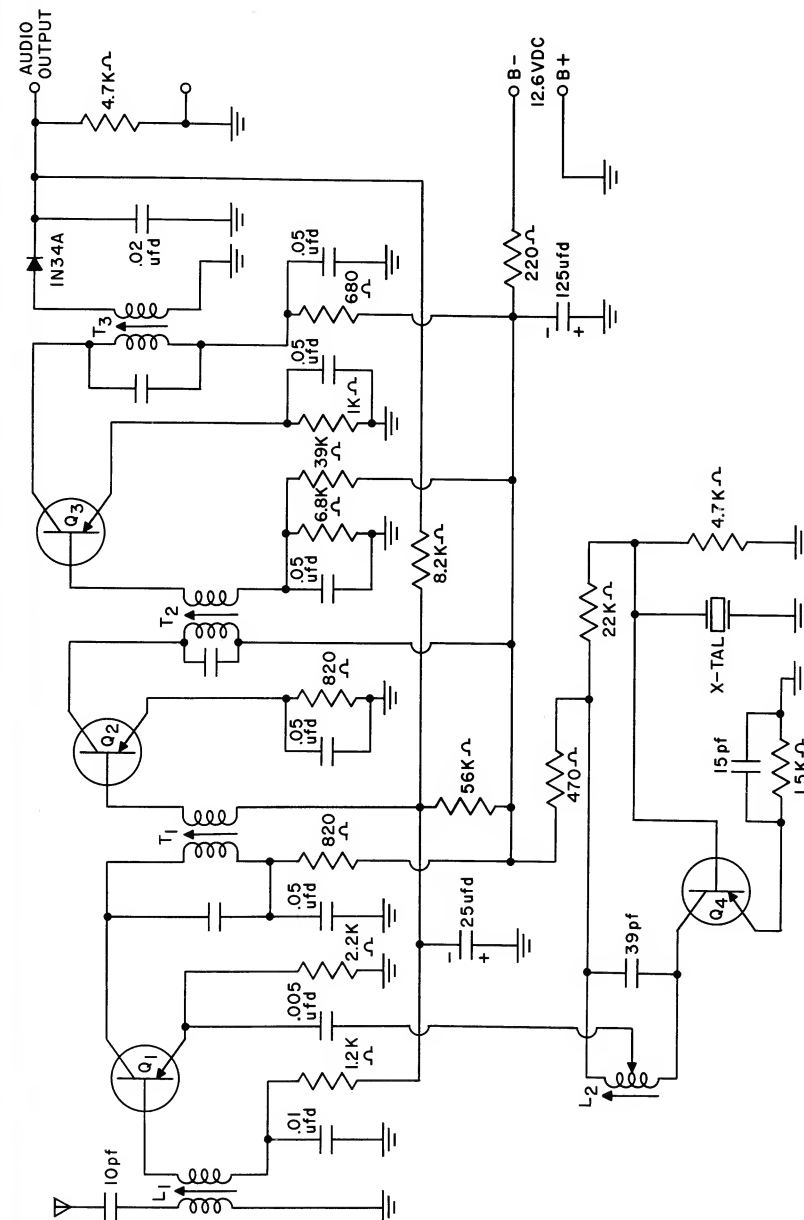
C₂ VALUES

67-150 cps	.3 ufd
150-650 cps	.25 ufd
650-800 cps	.2 ufd
800-1600 cps	.1 ufd

The detector operates as a self-quenched oscillator. The audio output of this circuit must be filtered to remove the quench signal. The filtered output is fed to an amplifier that will drive a resonant reed (similar to figure 24).



Q4 is a local oscillator stage utilizing a third overtone crystal. Q1 is the RF amplifier-mixer stage. Q2 and Q3 are 455 KC I.F. amplifiers. The 1N34A is the detector. Sensitivity is approximately 2 uv for a 10 db signal to noise ratio. The audio output is fed to an amplifier that will drive a resonant reed (similar to figure 24).



SECTION III. APPLICATION BLOCK DIAGRAMS

The reliability and economy available through application of resonant reeds is proven repeatedly not only in military equipment but also in such cost-conscious consumer applications as remote television controls and automatic garage door openers.

The ability of resonant reeds to withstand severe shock and vibration makes practical their use in mobile communications systems and other rough-duty applications.

This section shows some of the ways in which resonant reeds are presently being used. Others may suggest themselves. For assistance in specific areas of application, Bramco engineers — who have worked with many such problems — will be glad to offer their experience and knowledge.

FIGURE 46. GYRO OR SHAFT RPM INDICATOR

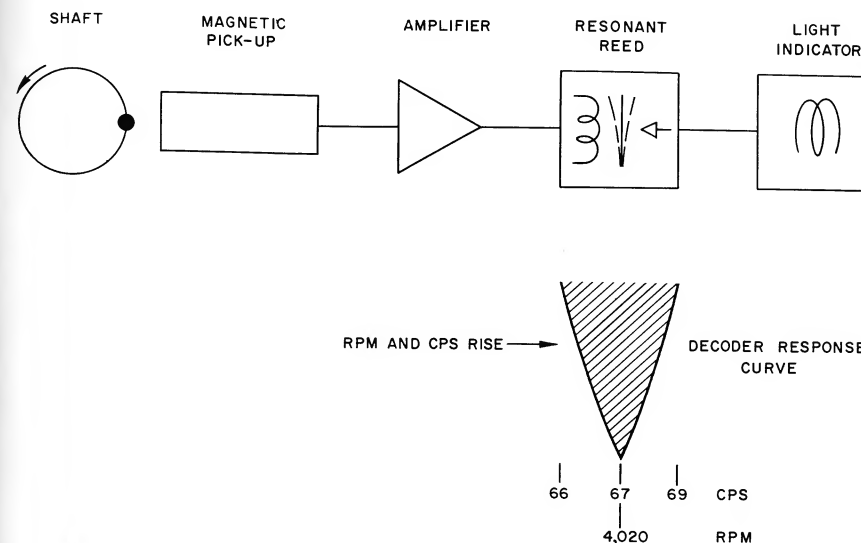


FIGURE 47. EMERGENCY ALERTING SYSTEM

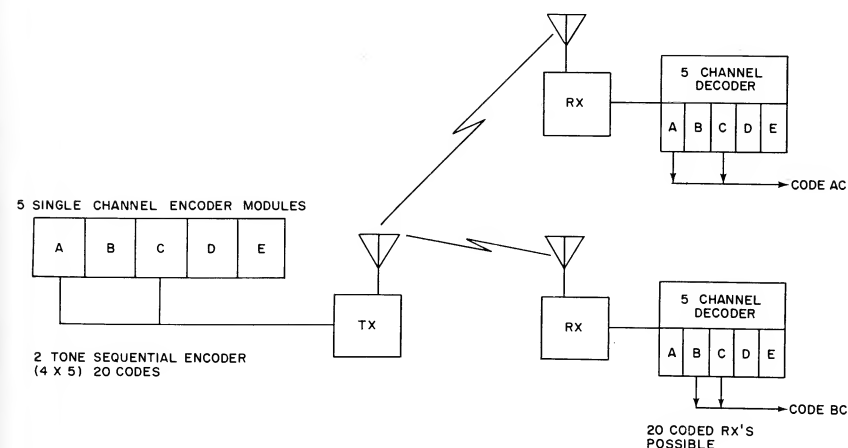


FIGURE 48.
TELEPHONE ANSWERING RECORDER WITH REMOTE PLAYBACK

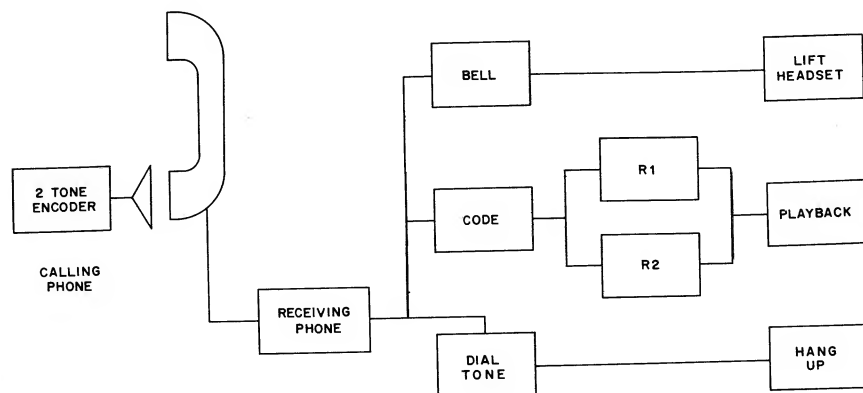


FIGURE 49. SUB-AUDIBLE SELECTIVE CALL SYSTEM

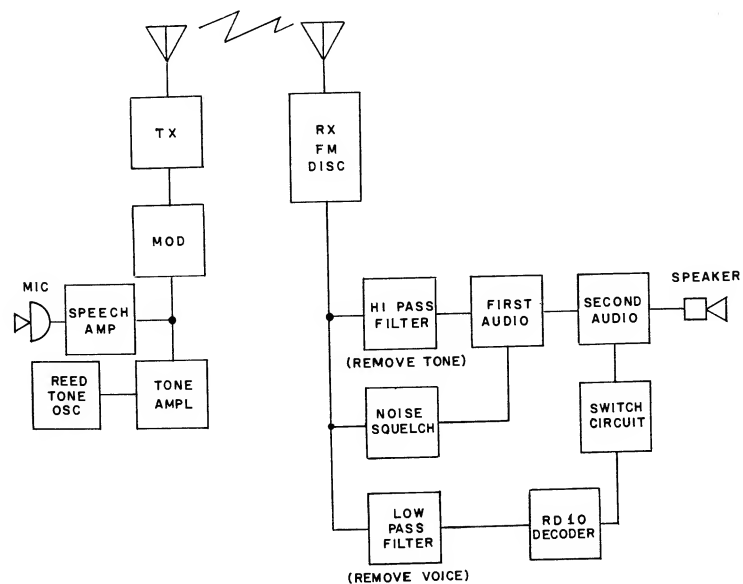


FIGURE 50. MISSILE PAD QUENCHING WATER CONTROL

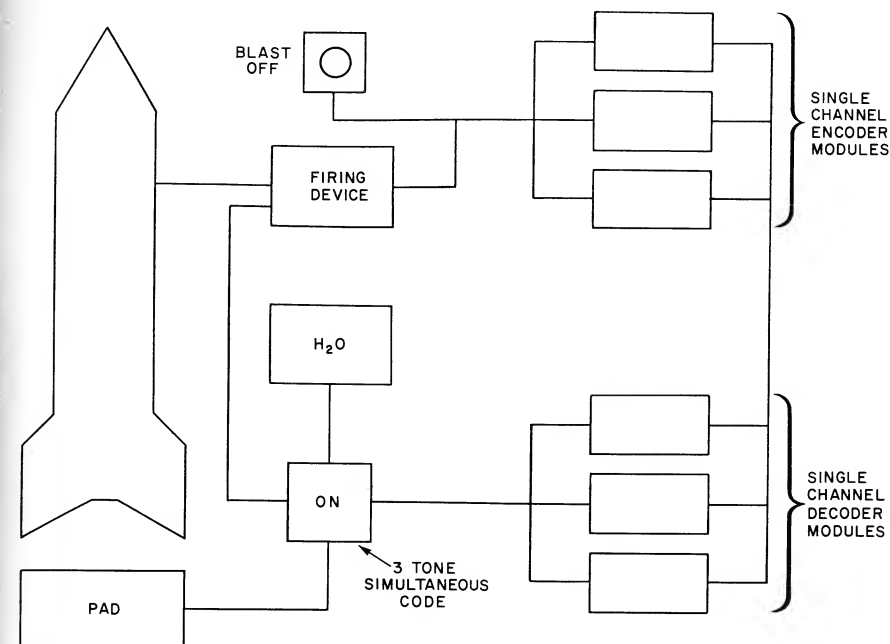


FIGURE 51. TAPE RECORD AND PLAY-BACK

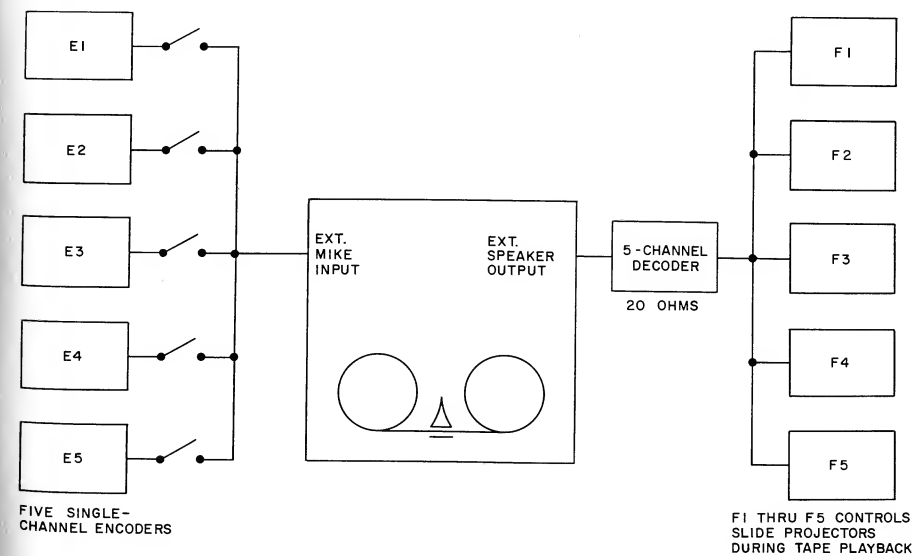


FIGURE 52. AIRCRAFT NAVIGATION

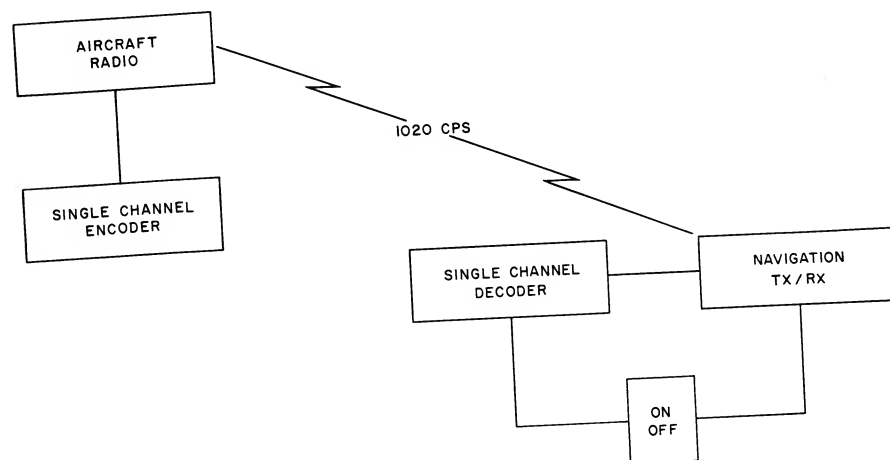


FIGURE 53. DC POWERED TIME CLOCK

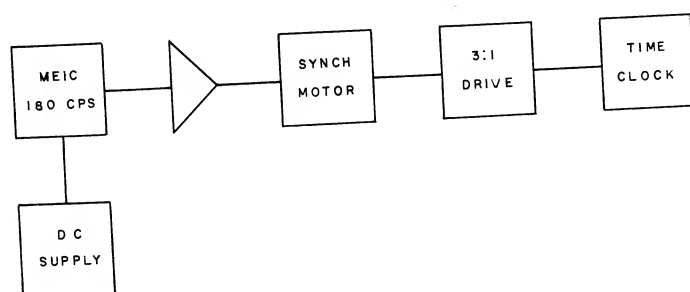


FIGURE 54. CARRIER CURRENT TONE CONTROL

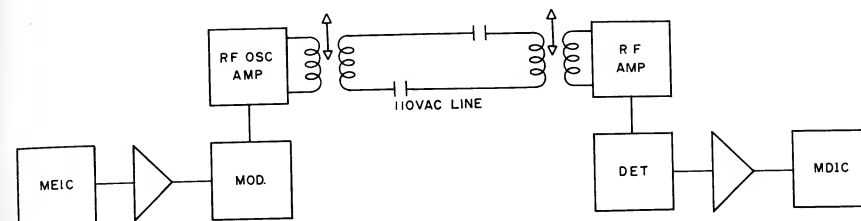
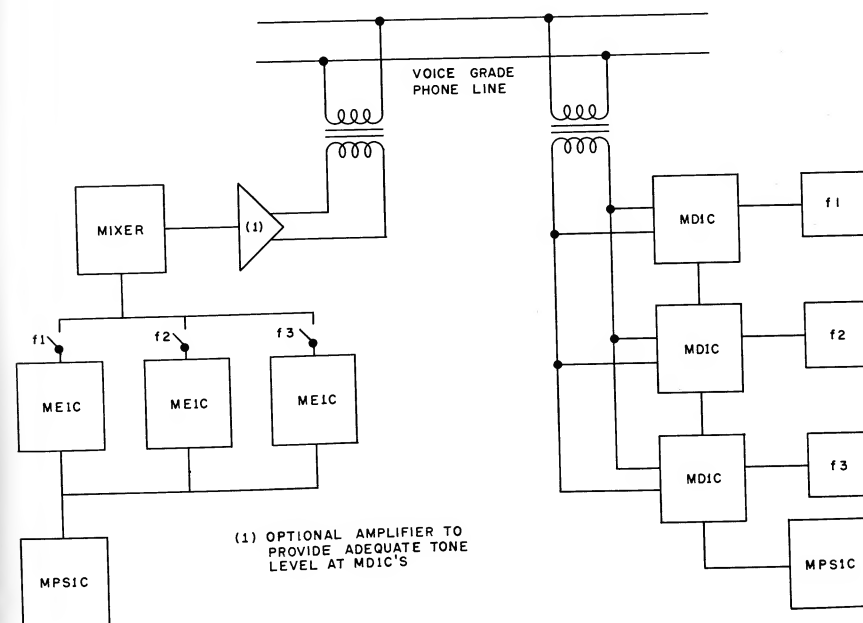


FIGURE 55. CONTROL SYSTEM OVER PHONE LINE



Bramco resonant reed components and modules

Bramco Controls Division manufactures a broad line of resonant reed encoder/decoder components and modules. Most often used, and generally available from stock, are the following. They have been specified for use in the schematic diagrams shown in Section II of this book and will provide optimum service and performance in the circuits described.

encoders

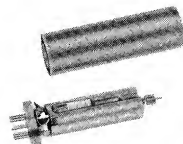
RE1 SINGLE CHANNEL RESONANT REED OSCILLATOR STABILIZER

$1\frac{3}{16}$ " dia. x $2\frac{1}{32}$ "

Frequency range: 300 to 1600 cps.

Frequency tolerance: $\pm .1\%$.

Hermetically sealed, internally shock mounted, 7 pin miniature tube base.



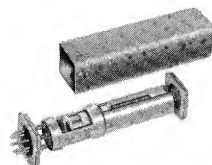
RE10 SINGLE CHANNEL RESONANT REED OSCILLATOR STABILIZER

.825" x .825" x 3.1"

Frequency range: 67 to 300 cps.

Frequency tolerance: $\pm .1\%$ or $\pm .1$ CPS, whichever is greater.

Hermetically sealed, internally shock mounted, 7 pin miniature tube base.



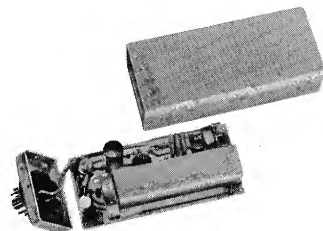
ME1C SINGLE CHANNEL RESONANT REED ENCODER MODULE

$1\frac{1}{2}$ " x 2" x $4\frac{1}{2}$ "

Frequency range: 67 to 1600 cps.

Frequency tolerance: $\pm .15\%$.

A complete transistorized oscillator circuit with built-in resonant reed stabilizer. Standard octal tube base.



decoders

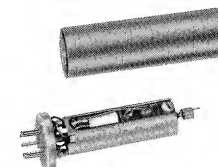
RD1 SINGLE CHANNEL FREQUENCY SENSING RESONANT REED RELAY

$1\frac{3}{16}$ " dia. x $2\frac{1}{32}$ "

Frequency range: 300 to 1600 cps.

Nominal bandwidth: $\pm .75\%$.

Hermetically sealed, internally shock mounted, 7 pin miniature tube base.



RD5 MULTI-CHANNEL FREQUENCY SENSING RESONANT REED RELAY

$1\frac{1}{2}$ " x $1\frac{1}{4}$ " x 1.3"

Frequency range: 200 to 600 cps.

Nominal bandwidth: $\pm 1\%$.

Available with from one to five reeds. Open frame construction.



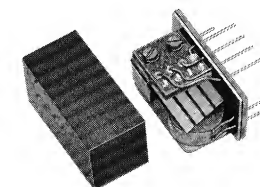
RD7C MULTI-CHANNEL FREQUENCY SENSING RESONANT REED RELAY

$1\frac{1}{64}$ " x $4\frac{3}{64}$ " x $4\frac{1}{64}$ "

Frequency range: 150 to 500 cps.

Nominal bandwidth: $\pm 1\%$.

Available with from one to four reeds. Miniaturized, with plastic dust cover and printed circuit mounting.



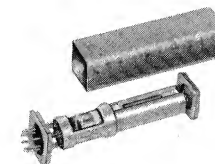
RD10 SINGLE CHANNEL FREQUENCY SENSING RESONANT REED RELAY

.825" x .825" x 3.1"

Frequency range: 67 to 300 cps.

Nominal bandwidth: $\pm 1.5\%$.

Hermetically sealed, internally shock mounted, 7 pin miniature tube base.



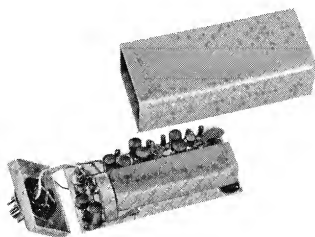
**MD1C SINGLE CHANNEL
RESONANT REED
FREQUENCY SENSING
DECODER MODULE**

$1\frac{1}{2}" \times 2" \times 4\frac{1}{2}"$

Frequency range: 67 to 1600 cps.

Nominal bandwidth: $\pm 1\%$.

A complete transistorized amplifier, resonant reed decoder, and secondary transistor switching circuit. Standard octal tube base.



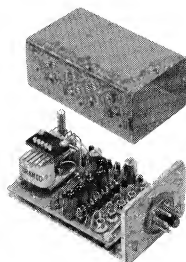
**MD5C FIVE CHANNEL
RESONANT REED
DECODER MODULE**

$2\frac{1}{8}" \times 2\frac{7}{8}" \times 5"$

Frequency range: 200 to 600 cps

Nominal bandwidth: $\pm 1\%$

A complete transistorized amplifier, multi-channel decoder with up to 5 secondary transistor switching circuits. Standard octal tube base.



**MPS1C REGULATED
SOLID STATE
DC POWER SUPPLY**

$2\frac{13}{16}" \times 4\frac{13}{16}" \times 4\frac{7}{8}"$

117 VRMS input

24 VDC output

Output current: 800 MA

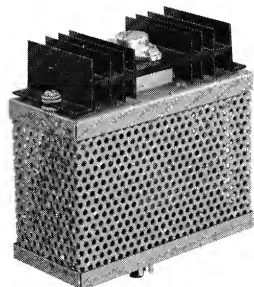
Line regulation: 1.5%

Load regulation: 2%

Ripple: .010 VRMS max.

Operating temperature range: -5°C to $+50^{\circ}\text{C}$

Compact, plug-in module with a well filtered output that is necessary for audio tone systems.



FOR LITERATURE LISTING COMPLETE PRODUCT SPECIFICATIONS, WRITE:

BRAMCO CONTROLS DIVISION, LEDEX INC.
College and South Streets Piqua, Ohio



*BRAMCO CONTROLS DIVISION, LEDEX INC.
College and South Streets, Piqua, Ohio 45356
Phone 513-773-8271*